CANADIAN THESES ON MICROFICHE

I.S.B.N.

THESES CANADIENNES SUR MICROFICHE

National Library of Canada
Collections Development Branch

Canadian Theses on
Microfiche Service

Ottawa, Canada
K1A 0N4

Bibliothèque nationale du Canada
Direction du développement des collections

Service des thèses canadiennes
sur microfiche

NOTICE

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

AVIS

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

NL-339 (r. 82/08)

Canada

181

0-315-16090-X

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Division
Division des thèses canadiennes

Ottawa, Canada
K1A 0N4

63999

PERMISSION TO MICROFILM — AUTORISATION DE MICROFILMER

• Please print or type — Écrire en lettres moulées ou dactylographier

Full Name of Author — Nom complet de l'auteur

RAKESH JAIN

Date of Birth — Date de naissance	Country of Birth — Lieu de naissance
March 5, 1956.	INDIA

Permanent Address — Résidence fixe

H-22 Green Park Extension.
NEW DELHI - 110016.
INDIA

Title of Thesis — Titre de la thèse

Efficacy and Behaviour of Three New selective Herbicides for Grass Weed Control.

University — Université

UNIVERSITY OF ALBERTA

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

M.Sc.

Year this degree conferred — Année d'obtention de ce grade	Name of Supervisor — Nom du directeur de thèse
1983	DR. W. H. Vanden Born

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

Date	Signature
April 19, 1983	R Jain

NL-91 (4/77)

THE UNIVERSITY OF ALBERTA

Efficacy and behaviour of three new selective herbicides for grass weed control

by

Rakesh Jain

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

IN

Weed Science

Plant Science

EDMONTON, ALBERTA

Spring 1983

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR Rakesh Jain

TITLE OF THESIS **Efficacy and behaviour of three new selective herbicides for grass weed control**

DEGREE FOR WHICH THESIS WAS PRESENTED Master of Science

YEAR THIS DEGREE GRANTED Spring 1983

Permission is hereby granted to THE UNIVERSITY OF ALBERTA LIBRARY to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly or scientific research purposes only.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

(SIGNED) .....Rjain.....

PERMANENT ADDRESS:

H-22 Green Park Extension

NEW DELHI - 110016

INDIA

DATED ...April 19.....1983

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled **Efficacy and behaviour of three new selective herbicides for grass weed control** submitted by Rakesh Jain in partial fulfilment of the requirements for the degree of Master of Science in Weed Science.

.....

Supervisor

.....G.R. Webster.....

.....A.W. Bailey.....

Date.....April 19, 1983

Abstract

Three new herbicides, BAS 9052 OH, TF 1169, and DOWCO 453, were evaluated for their efficacy and behaviour on annual and perennial grass weeds both in the field and in the greenhouse. All three herbicides provided effective control of wild oats, green foxtail, and volunteer barley at a range of growth stages. The efficacy of the herbicides, especially BAS 9052 OH and TF 1169, was dependent on weed species and the growth stage of the plants at the time of treatment. In general, the herbicides inhibited growth faster when applied at an early growth stage than at an advanced growth stage.

Herbicide injury symptoms were characterized by inhibition of growth and by chlorosis on leaves. Young and actively growing tissues were affected first. Stem elongation in wild oats was inhibited within 2 days of treatment with BAS 9052 OH and within 5 days of treatment with TF 1169 or DOWCO 453. At these observation times, rapidly elongating internodes showed a marked constriction near the base. These symptoms were followed by necrosis of the internode tissue in subsequent days. Histological examination of the affected internodes indicated that the herbicides inhibited lateral expansion and elongation of cells in the cortex and ground parenchyma regions. Herbicide injury symptoms in the anatomical structure appeared first in the peripheral regions of the stem tissue near the base of the rapidly elongating internodes. Cells in the

epidermis, cortex and procambium were most sensitive to injury from the herbicides. Necrosis then progressed to the centre of the stem tissue and all cells in the internode were killed within 14 days of treatment. All three herbicides behaved in a similar manner. It is proposed that the new herbicides affect growth in grasses predominantly by affecting cell division and cell elongation in rapidly elongating internodes.

All three herbicides appear to be readily translocated from the site of application on the leaves to the site of action in wild oats and green foxtail. Placement of a single droplet of the herbicide emulsion at different sites on the leaves induced injury symptoms similar to those observed after spray applications. Placement of the herbicide closer to the leaf base was more effective than placement away from the leaf base. The activity of TF 1169 on wild oats was affected most by site of application.

BAS 9052 OH appears to act faster than TF 1169 or DOWCO 453. Wild oat leaf treated with a single droplet of BAS 9052 OH emulsion had to remain attached to the rest of the untreated plant for 10 hours or more to kill the plant. Leaf treated with TF 1169 or DOWCO 453 had to remain attached to the rest of the untreated plant for at least 36 hours to kill the plant.

The efficacy of the new herbicides for wild oat control was not reduced when they were applied in combination with DOWCO 290 for broad-spectrum weed control in rapeseed. BAS

9052 OH, when applied at a reduced rate in combination with other herbicides such as barban, diclofop methyl or benzoylprop ethyl, also at reduced rates, provided as effective control of wild oats in rapeseed as when it was applied alone at the full rate. No injury to rapeseed plants was observed from any of the herbicide mixtures.

All three herbicides provided good control of quackgrass grown from planted rhizomes. Evaluation of quackgrass regrowth in herbicide-treated plots in the next growing season indicated that the treatments with DOWCO 453 were most effective in preventing regrowth. Barley grown in the herbicide-treated plots in the year after herbicide application was not affected. BAS 9052 OH or TF 1169 or mixtures of the two herbicides did not provide satisfactory control of established quackgrass in the field at the rates tested.

In greenhouse experiments, all three herbicides were very effective in controlling quackgrass and preventing regrowth from rhizomes. Herbicides applied to shoots at one end of rhizome sections consisting of ten nodes inhibited sprouting from most of the nodes, possibly due to translocation of the herbicides from the shoot to the rhizome system. Thus it appears that a potential may exist for selective control of quackgrass with these new herbicides.

Aknowledgements

I wish to express my deep sense of gratitude to my supervisor, Dr. W.H. Vanden Born, for his invaluable guidance and encouragement at every step during these investigations and constructive criticism of the manuscript. I am also grateful to him for the financial support given to me to sustain my studies.

My sincere thanks are due to Drs. Malcolm Devine and Najib Malik and my colleagues Hank Bestman and Chris Hall for their constant support and helpful counsel throughout the program.

A special thanks are extended to Ray Schraa for his technical assistance especially in preparing the photographs. Thanks are also due to Dominique Bizon and the summer students for their kind help in greenhouse and field experiments.

The University of Alberta is thanked for granting me permission to use their equipment and facilities.

The generous supply of herbicide samples for these investigations from BASF Canada Inc., Chipman Inc., and Dow Chemical of Canada, Limited is gratefully aknowledged.

I would like to express my appreciation and love to my parents for their encouragement during this project.

Table of Contents

Chapter Page

1. INTRODUCTION 1

2. LITERATURE REVIEW 4

2.1 BAS 9052 OH 4

2.1.1 Chemical and physical properties 4

2.1.2 Efficacy and selectivity 5

2.1.3 Physiological behaviour 8

2.1.4 Herbicide mixtures 10

2.2 TF 1169 11

2.2.1 Chemical and physical properties 11

2.2.2 Efficacy and selectivity 12

2.2.3 Physiological behaviour 14

2.2.4 Herbicide mixtures 15

2.3 DOWCO 453 16

2.3.1 Chemical and physical properties 16

2.3.2 Efficacy and selectivity 17

2.3.3 Morphological and physiological effects 18

2.3.4 Herbicide mixtures 18

2.4 Biology and Control of Wild Oats 19

2.5 Biology and Control of Green Foxtail 21

2.6 Biology and Control of Quackgrass 22

2.7 Structure and Growth of Wild Oat Stems 24

2.7.1 General morphology and growth 24

2.7.2 Mechanism of stem elongation 25

2.7.3 Anatomy 26

3. MATERIALS AND METHODS 28

3.1 General Procedures 28

3.1.1 Field experiments 28

3.1.2 Greenhouse experiments 30

3.2 Efficacy of the Herbicides for Grass Weed Control .32

3.2.1 Control of annual grasses in the field 32

3.2.1.1 Wild oat and volunteer barley control in rapeseed 32

3.2.1.2 Green foxtail control in rapeseed ...33

3.2.1.3 Annual grass weed control without crop and in crop 34

3.2.2 Effect on the growth of wild oats, green foxtail and barley 35

3.2.3 Quackgrass control in the field 36

3.2.3.1 Control of quackgrass grown from planted rhizomes 36

3.2.3.2 Control of established quackgrass ...37

3.2.4 Effect on the growth of quackgrass plants ...38

3.3 Morphological and Histological Effects 39

3.3.1 Plant material 39

3.3.2 Histological procedure 39

3.3.3 Observations recorded 41

3.4 Translocation Behaviour 43

3.4.1 Site of application of herbicides on grass weeds 43

3.4.2 Mutilation experiments 44

3.4.3 Viability of quackgrass rhizomes 45

3.5 Herbicide Mixtures 46

3.5.1 BAS 9052 OH mixtures with other wild oat herbicides 47

3.5.2 Herbicide mixtures with DOWCO 290 47

4. RESULTS AND DISCUSSION 49

4.1 Annual Grass Weed Control in Rapeseed 49

4.2 Annual Grass Weed Control Without Crop and in Crop 52

4.3 Effect of the Herbicides on Growth of Annual Grasses 58

4.3.1 Injury symptoms 58

4.3.2 Dry weight reductions 59

4.4 Quackgrass Control in the Field 65

4.4.1 Control of quackgrass grown from planted rhizomes 65

4.4.2 Control of established quackgrass 66

4.5 Effect of the Herbicides on Growth of Quackgrass ..67

4.5.1 Injury symptoms 67

4.5.2 Dry weight of shoots and viability of rhizomes 68

4.6 Morphological and Histological Effects on Wild Oats 73

4.6.1 Injury symptoms on the stem 73

4.6.2 Anatomical structure 73

4.6.3 Stem length 87

4.6.4 Culm diameter 91

4.6.5 Vascular bundle diameter 92

4.6.6 Diameter of cells in the cortex 93

4.6.7 Width of cells in the ground parenchyma 94

4.6.8 Length of cells in the cortex 96

4.6.9 Length of cells in the ground parenchyma 97

4.7 Translocation Behaviour of the Herbicides in Grasses 100

4.7.1 Effects of site of application on wild oats 100

4.7.2 Effects of site of application on green foxtail 103

4.7.3 Mutilation studies on wild oats 107

4.8 Viability of Quackgrass Rhizomes 111

4.9 Herbicide Mixtures 117

4.9.1 Mixtures with other wild oat herbicides 117

4.9.2 Grass weed control with DOWCO 290 mixtures .119

5. CONCLUSION 123

BIBLIOGRAPHY 129

APPENDIX 144

List of Tables

Table — Page

1. Information on experimental sites.....29
2. Wild oat and volunteer barley control in rapeseed (1981).....50
3. Green foxtail control in rapeseed (1981).....51
4. Control of wild oats without crop and in crop.....53
5. Control of green foxtail without crop and in crop.....54
6. Control of volunteer barley without crop and in crop..56
7. GR_{50} values of the herbicides on grass weeds.....63
8. Control of quackgrass grown from planted rhizomes in the field.....65
9. Control of established quackgrass.....67
10. Regrowth of quackgrass in the greenhouse.....70
11. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on culm diameter.....91
12. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on vascular bundle diameter.....92
13. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on diameter of cells in the cortex.....94
14. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on width of cells in the ground parenchyma.....95
15. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on cell elongation in the cortex.....96
16. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on cell elongation in the ground parenchyma.....97
17. Dry weight of quackgrass shoots 15 days after treatment.....112
18. Viability of individual quackgrass rhizome nodes after treatment of the shoots with BAS 9052 OH.....113
19. Viability of individual quackgrass rhizome nodes after treatment of the shoots with TF 1169.....114

20. Viability of individual quackgrass rhizome nodes after treatment of the shoots with DOWCO 453.....115

21. Mixtures of BAS 9052 OH with other herbicides for wild oat control in rapeseed.....117

22. Herbicide mixtures with DOWCO 290 for green foxtail control without crop and in crop.....119

23. Herbicide mixtures with DOWCO 290 for wild oat control without crop and in crop.....120

24. Herbicide mixtures with DOWCO 290 for volunteer barley control without crop and in crop.....121

List of Figures

Figure — Page

Ia. Diagrammatic representation of a transverse section of wild oat stem.....42

Ib. Diagrammatic representation of a longitudinal section of wild oat stem.....42

1a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of wild oat plants, 15 days after treatment at the 2-leaf stage.....60

1b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of wild oat plants, 15 days after treatment at the 4-leaf stage.....60

2a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of green foxtail plants, 15 days after treatment at the 2-leaf stage.....61

2b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of green foxtail plants, 15 days after treatment at the 4-leaf stage.....61

3a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of barley plants, 15 days after treatment at the 2-leaf stage.....62

3b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of barley plants, 15 days after treatment at the 4-leaf stage.....62

4a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the dry weight of quackgrass plants, 15 days after treatment at the 2-leaf stage.....69

4b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the dry weight of quackgrass plants, 15 days after treatment at the 4-leaf stage.....69

5. Part of the stem of wild oats showing the third, fourth and upper internodes and the panicle (untreated).....74

6. Part of the stem of wild oats 2 days (A) and 5 days (B) after treatment with DOWCO 453 at 0.05 kg/ha.....75

7. Part of the stem of wild oats 9 days (A) and 14 days (B) after treatment with DOWCO 453 at 0.05 kg/ha.....76

8. Part of the stem of wild oats 14 days after treatment with TF 1169 (0.1 kg/ha) (A), and with BAS 9052 OH (0.1 kg/ha) (B).....77

9. Transverse section of wild oat stem from near the base of the fourth internode showing the epidermis, vascular bundles, and the parenchymatous tissue in the cortex and ground parenchyma (untreated).....80

10. Transverse section of wild oat stem from near the base of the fourth internode showing the epidermis, the sclerenchymatous tissue, protophloem, metaphloem, xylem and the parenchymatous tissue in the cortex and ground parenchyma (untreated).....80

11. Longitudinal section of a part of wild oat stem showing the fourth internode, the upper internodes and the panicle (untreated).....82

12. Transverse sections of wild oat stem from near the base of the fourth internode of plants treated with BAS 9052 OH at 0.1 kg/ha.....84

13. Longitudinal sections of the fourth internode of wild oat stem of plants treated with BAS 9052 OH at 0.1 kg/ha.....86

14a. Effect of BAS 9052 OH on wild oat stem elongation during 14 days after treatment.....88

14b. Effect of BAS 9052 OH on the elongation of the second, third, and fourth internodes during 14 days after treatment.....88

15a. Effect of TF 1169 on wild oat stem elongation during 14 days after treatment.....89

15b. Effect of TF 1169 on the elongation of the second, third, and fourth internodes during 14 days after treatment.....89

16a. Effect of DOWCO 453 on wild oat stem elongation during 14 days after treatment.....90

16b. Effect of DOWCO 453 on the elongation of the second, third, and fourth internodes during 14 days after treatment.....90

17. Effect of site of application of BAS 9052 OH on the dry weight of wild oat plants, 15 days after treatment.....101

18. Effect of site of application of TF 1169 on the dry weight of wild oat plants, 15 days after treatment...101

19. Effect of site of application of DOWCO 453 on the dry weight of wild oat plants, 15 days after treatment...102

20. Effect of site of application of BAS 9052 OH on the dry weight of green foxtail plants, 15 days after treatment.....104

21. Effect of site of application of TF 1169 on the dry weight of green foxtail plants, 15 days after treatment.....104

22. Effect of site of application of DOWCO 453 on the dry weight of green foxtail plants, 15 days after treatment.....105

23. Effect of different periods of treatment with BAS 9052 OH, TF 1169, and DOWCO 453 on the dry weight of wild oat plants, 15 days after treatment.....109

1. INTRODUCTION

Annual grass weeds present a serious problem in broad-leaved crops such as rapeseed. Wild oats is the most serious annual grass weed in the prairie provinces and estimates of total annual losses due to this weed in 1973 varied from $ 120 million to $ 500 million (cited in 119). Green foxtail has become more prevalent in recent years (2,17,127) and can reduce crop yields when present in dense competitive stands (55,70,108). Volunteer cereals can become a problem where they are grown in rotation with rapeseed.

Several control measures, both cultural and chemical, have been developed over the years for the control of these grass weeds (12). Until the mid-1970's, chemical control measures were mainly dominated by soil-applied herbicides. However, these herbicides have their limitations in terms of energy inputs or inconsistency in control as a result of variations in climate and soil (116,123). This is particularly true with trifluralin (58). Postemergence herbicides available before 1975 were restricted in their applicability because of the limited spectrum of grasses controlled, the critical timing for spraying, or their marginal selectivity towards crop plants (116,123). Barban and benzoylprop ethyl are examples of such herbicides (12,54,56). Diclofop methyl has proved to be very effective against some grass weeds but it does not control volunteer cereals (30,59). Also, its activity may be reduced under unfavourable environmental conditions such as low

temperature and drought stress (42).

The advent of the new grass herbicides, BAS 9052 OH, TF 1169, and DOWCO 453, holds considerable promise for highly selective, postemergence grass weed control in a variety of broad-leaved crops. The objectives of the present study were to evaluate the efficacy of these new herbicides for wild oat, green foxtail, and volunteer barley control in rapeseed at a range of growth stages of weeds/crop and to investigate the site and nature of their phytotoxic activity in wild oats and their translocation from the site of application on the leaves to the site of action in wild oats and green foxtail. Since the new herbicides are active only against grass weeds, a combined application of these herbicides with DOWCO 290, a selective postemergence herbicide for broad-leaved weed control, also was tested with a view to obtaining broad-spectrum weed control in rapeseed with a single application. Mixtures of BAS 9052 OH with other herbicides for wild oat control were tested to improve the efficacy of the herbicides for wild oat control.

Quackgrass is a troublesome perennial grass weed that spreads by means of both seeds and rhizomes (8,70,129). Control of this weed until recently was largely dependent on cultural control practices such as repeated tillage. The introduction of glyphosate has encouraged quackgrass control by chemical means. However, glyphosate is non-selective, hence it must be applied in a non-crop year or in the spring before seeding or in the fall after harvest. Spring and fall

applications of glyphosate in Western Canada are restricted by a short growing season. The present investigations were conducted to examine the efficacy of the new grass herbicides for control of quackgrass in the field. The viability of rhizomes following foliar applications of BAS 9052 OH, TF 1169, and DOWCO 453 was tested, both in the greenhouse and in the field, to examine the translocation behaviour of these herbicides in quackgrass and their ability to prevent regrowth in the subsequent growing season.

2. LITERATURE REVIEW

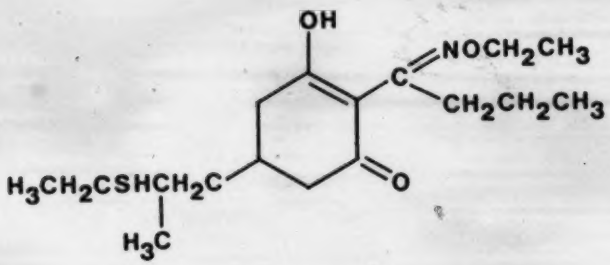
BAS 9052 OH, TF 1169, and DOWCO 453 are new herbicides developed in Canada for selective, broad-spectrum grass weed control in a variety of broad-leaved crops. The present discussion summarizes the information available in the literature regarding the chemical and physical properties of the new herbicides and their behaviour in plants as well as the biology of the grass weeds - wild oats, green foxtail, and quackgrass. A knowledge of the growth characteristics and anatomical structure of wild oats is important to an understanding of the effects of the new herbicides on the morphology and histology of this weed species.

2.1 BAS 9052 OH

2.1.1 Chemical and physical properties

BAS 9052 OH' [(2-(1-(ethoxyimino)butyl)-5-(2-ethylthio) propyl)-3-hydroxy-2-cyclohexene-1-one] is a new herbicide being developed in Canada by BASF Canada Inc. (3). The chemical structure of the active ingredient is as follows:

'The proposed common name for this herbicide in Canada and the U.S.A. is 'sethoxydim'.



BAS 9052 OH is a liquid emulsifiable concentrate formulation containing 184 g active ingredient per litre. The active ingredient is an odourless, reddish brown, oily liquid that is poorly soluble in water (24.5 ppm at 25°C) but freely soluble in several organic solvents. It is a low volatile compound with a vapour pressure of 1.3 X 10^{-3} kPa at 20°C (3,73).

The herbicide has a low toxicity to all plant and animal forms tested except for target grass species. The acute oral LD_{50} on rats is 2000 to 5000 mg/kg (3,73).

2.1.2 Efficacy and selectivity

BAS 9052 OH has shown excellent potential for selective postemergence grass weed control in a variety of broad-leaved crops. It has exhibited some preemergence activity, however, its persistence in soil is very short due to its rapid breakdown in soil (73). The half-life of BAS 9052 OH was estimated to be 4 to 5 days in loamy sand at pH 6.8 and 11 days in a loam soil at pH 7.4. Consequently,

preemergence activity of BAS 9052 OH was not considered adequate for grass weed control (3).

Results of extensive field trials in Canada have indicated that this herbicide can be used safely in rapeseed, flax, soybeans, and sugarbeets at nearly all stages of growth (3,104). Effective control of a variety of annual and perennial grasses, including volunteer wheat and barley, has been obtained at a wide range of growth stages and environmental conditions (48,113). Barley was most tolerant and green foxtail was most susceptible among the annual grasses tested (48). Reports of excellent selective control of many other grass weeds by BAS 9052 OH in various broad-leaved crops are also available from several other countries (26,44,64,104,134,135).

Repeat applications frequently were required for perennial grass control depending on species, stage of growth, and environmental conditions (71,74,84,104,135). Established stands of perennial grasses, including quackgrass grown from rhizomes, generally required higher rates of the herbicide than new growth from seeds (21,37,67,104). In established stands of quackgrass, cultivation 2 or 7 days after emergence did not affect the level of control obtained (74).

The stage of development of grass species at spray time affected the efficacy of BAS 9052 OH (28,104). Applications of the herbicide at an early (2- to 4-leaf) growth stage of some annual grasses were more effective than applications at

a late (4- to 6-leaf) growth stage (28,64,67,84,98). Control of annual grasses generally was ineffective at the heading stage (64,98). However, in the case of perennial grasses, applications from the late boot to the early seed-fill stage provided better initial and regrowth control than did earlier treatments (66,104,113,135).

The addition of an oil or oil concentrate (mixture of oil and surfactant) to the final spray volume frequently increased the activity of BAS 9052 OH (48,104). Chow (29) reported that the addition of a non-ionic surfactant such as Atplus 411F (17% polyoxyethylene sorbitan fatty acid ester in mineral oil) at 0.5% (v/v) of the spray volume increased the herbicidal activity of BAS 9052 OH on wild oats. The addition of ammonium sulfate in combination with the surfactant further increased the efficacy of the herbicide. Additional reports from field experiments have confirmed the effectiveness of Atplus 411F as an adjuvant with BAS 9052 OH on various other grass weeds (28,48,135).

Efficacy of BAS 9052 OH generally was greatest under moisture conditions that were favourable for plant growth. Under conditions of drought stress, activity of the herbicide was reduced, particularly at advanced growth stages of grasses (28,84).

2.1.3 Physiological behaviour

Available information on the translocation characteristics of BAS 9052 OH has indicated that the herbicide is translocated to all plant parts following foliar applications (74,113,124). In quackgrass, ^{14}C-labeled BAS 9052 OH moved through the rhizomes to daughter plants. These results were consistent with the effects observed on quackgrass in the field (23).

The absorption of BAS 9052 OH through the leaves of barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] was rapid, with 90% of the applied herbicide absorbed within 12 hours or less. Negligible amounts of BAS 9052 OH were absorbed through the roots as compared to foliar absorption. No major differences in absorption and translocation were evident in susceptible and resistant species (23). The selectivity of BAS 9052 OH was attributed to factors such as rapid metabolism and exudation of the herbicide through the roots in broad-leaved plants (124).

BAS 9052 OH has been observed to affect the meristematic tissue in above and below-ground parts of grasses (104,125). Treated plants of johnsongrass [*Sorghum halepense* (L.) Pers.] and itchgrass (*Rottboellia exaltata* L.F.) stopped growing and developed visible necrosis in the meristems within 72 hours of treatment. Cells in this region showed a lack of mitotic figures (78). In corn seedlings, BAS 9052 OH inhibited the initiation and growth of adventitious roots and caused swelling at the root tips (7).

Chandler and Paul (27) reported that BAS 9052 OH did not affect the cross-sectional area of the vascular bundles in the leaf tissue of treated bermudagrass [*Cynodon dactylon* (L.) Pers.] plants. The primary effect of the herbicide on the leaf tissue occurred in the mesophyll cells. Mesophyll cell mitochondria showed a loss of matrix density and of some internal membrane organization following application of the herbicide. Bundle sheath cells were not affected by the treatments.

Gealy and Slife (60) observed an inhibition of photosynthesis and transpiration in treated corn leaves. Total chlorophyll content in the leaves was reduced, possibly due to inhibition of chlorophyll synthesis (7). However, Hatzios (65) reported that photosynthesis was not significantly affected by BAS 9052 OH. Protein and ribonucleic acid (RNA) synthesis were affected only by the highest concentration (100 μM) of the herbicide tested. Lipid synthesis was the most sensitive of all the metabolic processes examined and was inhibited by all concentrations (0.1 to 100 μM) of BAS 9052 OH following treatment for 60 to 120 minutes. It was suggested that BAS 9052 OH could bring about its phytotoxic action by altering the lipid composition of plant membranes (65).

2.1.4 Herbicide mixtures

BAS 9052 OH is ineffective against broad-leaved weeds. Pearson (104) suggested that the flexibility in application timing of BAS 9052 OH could allow for combinations of this herbicide with some postemergence herbicides for broad-leaved weeds to achieve broad-spectrum weed control.

Several reports (49,50) from field experiments have indicated that the efficacy of BAS 9052 OH was not affected when it was applied in combination with DOWCO 290[2] (3,6-dichloropicolinic acid). Rapeseed was not injured by this mixture. However, other reports (49,50) indicated that BAS 9052 OH in combination with DOWCO 290 caused some injury to rapeseed, especially to the cultivar 'Tower', and reduced the seed yield of the crop. When BAS 9052 OH was applied in combination with DOWCO 290 and benazolin (4-chloro-2-oxobenzothiazolin-3-ylacetic acid), wild oat control was reduced (50). No antagonism was observed in wild oat, green foxtail, and broad-leaved weed control when BAS 9052 OH was applied in combination with the amine or potassium salt of MCPA (2-methyl-4-chlorophenoxyacetic acid) or a combination of propanil (3',4'-dichloropropionanilide) and bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) in flax (50).

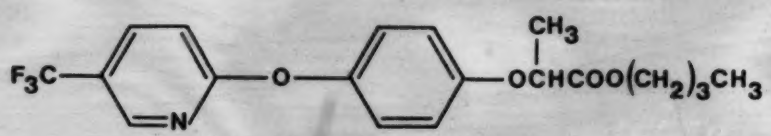
---

[2] A selective, postemergence, experimental herbicide being developed by Dow Chemical of Canada Limited, for the control of several broad-leaved weeds in crops such as rapeseed.

2.2 TF 1169

2.2.1 Chemical and physical properties

TF 1169[3] [butyl-2-(4-(5-trifluoromethyl-2-pyridyloxy) phenoxy)propanoate] is a new selective herbicide developed in Canada by Chipman Inc. This herbicide is being jointly developed all over the world since 1978 by Ishihara Sangyo Company and Imperial Chemical Industries Limited under the proposed common name fluazifop butyl (81). The chemical structure of the active ingredient is as follows :



Kimura et al. (81) suggested that the substitution of CF_3 at the 5-position of the pyridine ring of TF 1169 was important in enhancing its herbicidal and translocation ability in grasses.

TF 1169 is formulated as a liquid emulsifiable concentrate containing 250 g of active ingredient per litre. The active ingredient is a low-volatile compound with a vapour pressure of 5.5×10^{-3} kPa at 20°C. It is an

---

[3]This herbicide is being developed under the code name PP 009 in other countries.

odourless, light-straw-colored liquid that is poorly soluble in water (2 ppm) but freely soluble in many organic solvents (106).

The herbicide and its major metabolites have low mammalian toxicity. The acute oral LD_{50} and dermal LD_{50} to rats were approximately 3000 mg/kg and more than 5000 mg/kg, respectively (4,106).

2.2.2 Efficacy and selectivity

Extensive field trials have shown that TF 1169 can be used safely in over 60 different temperate and tropical broad-leaved crops for highly selective grass weed control over a wide range of crop/weed growth stages and environmental conditions (52,81,106,117). Soybeans sprayed after emergence and at the flowering stage were not affected by rates as high as 3 kg/ha (114). Excellent and consistent postemergence control of annual grass weeds was achieved at rates of 0.125 to 0.5 kg/ha. Perennial grass weeds required 0.5 to 2.0 kg/ha of the herbicide for effective control (4,81,106).

In general, TF 1169 provided better control of annual and perennial grass weeds than BAS 9052 OH (64). Some reports, however, indicated that TF 1169 was less effective on barnyardgrass and green foxtail than BAS 9052 OH (41,47,98). The efficacy of TF 1169 was dependent on the stage of growth of annual grasses at the time of treatment (98). Higher rates of the herbicide were generally required

to control grass weeds at an advanced (4- to 6-leaf) stage than at an early (2- to 4-leaf) stage (41). TF 1169 at rates up to 0.67 kg/ha did not control annual grasses such as giant foxtail (*Setaria faberii* Herrm.) and barnyardgrass that were older than the 5-leaf stage (98).

TF 1169 has been particularly effective against perennial grass weeds including quackgrass and johnsongrass (32,33,52). Anderson (47) reported that treatments with TF 1169 at 0.5 kg/ha or more on quackgrass at the 3- to 4-leaf stage were as effective as glyphosate [*N*-(phosphonomethyl) glycine] at 1.5 kg/ha. Treatments applied at an advanced (4- to 6-leaf) growth stage of quackgrass were more effective than treatments at an early (3- to 4-leaf) growth stage (47).

Several reports have indicated that fragmentation of the perennating organs of perennial grasses before treatment improved the efficacy of TF 1169 and resulted in better control. Higher rates were required for the control of growth from unfragmented rhizomes (33,47,50,117). However, with increased cultivation, where plots were rototilled in the spring after ploughing in the preceding fall, treatments with TF 1169 resulted in poor control of quackgrass (47).

The addition of a leaf-wetting surfactant, Agral 90[4], at 0.1% (v/v) of the spray volume, or an oil concentrate at 2.34 L/ha, to the spray solution generally improved the efficacy of TF 1169 (4,32,106). Under favourable soil

---

[4]90% alkyl phenol ethylene oxide condensate.

moisture conditions for plant growth, the herbicide provided more effective control of johnsongrass growing from rhizomes than under drought stress conditions (33,47).

TF 1169 is primarily a postemergence herbicide. It was reported that it could also be applied to the soil as a preemergence or preplant incorporated treatment. However, when applied to the soil, higher rates were required to achieve the same level of control as that obtained with postemergence applications (32). Persistence of the herbicide in soil was short, 3 to 6 weeks in the field depending on soil temperature and moisture conditions. Cold, dry conditions prolonged persistence of TF 1169 in soil (4).

2.2.3 Physiological behaviour

TF 1169 was translocated in both the xylem and the phloem following postemergence applications (106,114). It was suggested that the herbicide was absorbed through the leaves and translocated in the phloem to the rhizomes in quackgrass and johnsongrass (81). Translocation into johnsongrass rhizomes occurred much more rapidly in plants growing under favourable soil moisture conditions than under moisture stress conditions (110).

Kimura et al. (81) reported that TF 1169 moved much more readily in the stolons of bermudagrass than other "translocating" herbicides including glyphosate. It inhibited sprouting from all the nodes on the stolon, whereas glyphosate did not prevent sprouting from nodes

beyond the fifth one from the treated part (81).

The action of TF 1169 on grasses is slow, especially at low temperatures (4,81,106). Injury symptoms in susceptible plants usually were not evident until a week after treatment, although growth ceased within 48 hours of application. The characteristic symptoms were chlorosis followed by necrosis on young leaves and accumulation of anthocyanin in old leaves. Meristematic tissue in the nodes and growing points became necrotic. This initial loss of vigour, and the senescence of young leaves and meristems, later spread to the whole plant and death was usually complete within 3 to 5 weeks of treatment (4,81,106). It was suggested that TF 1169 adversely interfered with adenosine triphosphate (ATP) production in susceptible plants (106).

The selectivity of TF 1169 was believed to be due to rapid degradation followed by conjugate formation in broad-leaved plants (4,106). The parent herbicide or its metabolites were not detected in potato and sugarbeet samples 12 weeks after treatment (4).

2.2.4 Herbicide mixtures

TF 1169, when applied in combination with some herbicides for broad-leaved weeds, provided excellent broad-spectrum weed control without causing injury to crop plants (41,114). However, tank-mix applications of TF 1169 with benazolin and DOWCO 290 caused injury to rapeseed (4,47). In some instances, antagonism in weed control was

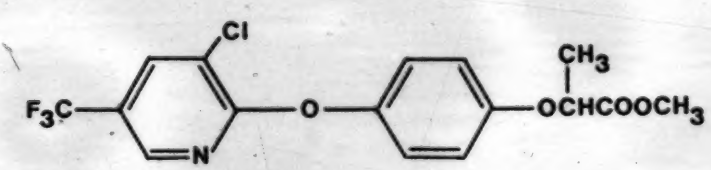
observed when these herbicides were applied as a tank mixture (47). A reduction in grass weed control by TF 1169 was also observed when it was applied in combination with MCPA, but to a lesser extent in combination with bromoxynil/MCPA (1:1) (4).

It was suggested that crop damage resulting from the use of TF 1169 in tank mixtures with various herbicides for broad-leaved weeds could be eliminated by applying the herbicides sequentially with an interval of 5 to 7 days between sprays (4).

2.3 DOWCO 453

2.3.1 Chemical and physical properties

DOWCO 453[a] [methyl 2-(4-(3-chloro-5-(trifluoromethyl)-2-pyridinyl)phenoxy)propanoate] is a new selective, postemergence herbicide being developed in Canada by Dow Chemical of Canada, Limited. The chemical structure of the active ingredient of this herbicide is as follows:



---

[a] The proposed common name of this herbicide in Canada is 'haloxyfop methyl'.

DOWCO 453 is formulated as a liquid emulsifiable concentrate with 240 g active ingredient per litre. The solubility in water of the active ingredient of DOWCO 453 is 0.84 ppm. It appears to be a low-volatile compound (5). The herbicide showed very little leaching in soil, suggesting strong adsorption of the herbicide to soil organic matter (5).

DOWCO 453 has a low acute toxicity to animals. Acute oral LD_{50} values in female and male rats are 2178 mg/kg and 2397 mg/kg, respectively (5,6).

2.3.2 Efficacy and selectivity

DOWCO 453 has exhibited excellent herbicidal activity against most annual and perennial grass species in the field. Effective postemergence control of annual grasses was obtained at rates as low as 0.07 to 0.28 kg/ha. It also has some soil residual activity for the control of later-germinating grasses. However, the persistence of the herbicide in soil was short, with a half-life of about 4 weeks (5). All broad-leaved crops tested showed high tolerance to DOWCO 453 (5,6,38,47,50,121). Regent rapeseed sprayed at the 6- to 7-leaf stage and Candle rapeseed sprayed up to early bloom stage were not injured by high rates (0.30 kg/ha) of the herbicide (50).

Results of experiments on quackgrass control with DOWCO 453 indicated that the herbicide provided effective control of this perennial weed over a range of growth stages.

However, applications at the 4- to 5-leaf stage were generally more effective than earlier applications (38). Applications late in the season, at the early heading stage, did not provide effective control of quackgrass at low rates (0.13 kg/ha) of application (47).

In general, DOWCO 453 was more toxic to grass species than BAS 9052 OH or TF 1169 at similar rates of application (47,98). The efficacy of the herbicide was improved by the addition of a non-ionic surfactant or an oil concentrate at 0.5% (v/v) of the spray volume (5,6,121).

2.3.3 Morphological and physiological effects

DOWCO 453 was most effective when the weeds were young and growing actively. First herbicide injury symptoms appeared after a latent period of several days at which time shoot and root growth ceased. On barley, yellowing was visible 6 days after treatment. A mottled chlorosis became evident on the leaves and later spread to all plant parts. By 2 weeks after treatment, the plants wilted and died following tissue desiccation (5,50). It was suggested that DOWCO 453 was a 'photosynthetic inhibitor type' herbicide (5).

2.3.4 Herbicide mixtures

DOWCO 453, like BAS 9052 OH and TF 1169, does not show any activity against broad-leaved weeds. Hence, several tests have been conducted to evaluate the compatibility of

DOWCO 453 with some herbicides for broad-leaved weeds to achieve broad-spectrum weed control.

A tank-mix application of DOWCO 453 and DOWCO 290 at suggested field rates of each herbicide showed good compatibility and provided effective control of grass weeds including wild oats and volunteer barley (47). The mixture did not cause any injury to rapeseed or to transplanted cabbage or cauliflower (47). In some instances, however, rapeseed yields were reduced following application of the mixtures (50).

2.4 Biology and Control of Wild Oats

Wild oats (*Avena fatua* L.) is one of the most troublesome annual grass weeds of cultivated land in the three prairie provinces of Canada - Alberta, Saskatchewan and Manitoba (1,119,136). In North America, wild oats is rated by far the most serious weed of almost the entire cultivated portion of the northern part of the Great Plains region. The total area infested with wild oats in Canada and the United States in 1970 was estimated at over 26 million hectares (95,136).

Wild oats is particularly adapted to grow in arable land (136). Pavlychenko and Harrington (103) reported that wild oat plants have good competitive ability because of their rapid rate of growth, the extent and natural distribution of the root system, the rate and extent of

germination, and their seed persistence. They can markedly reduce the yield of rapeseed (40), wheat (14,20), barley (14), and flax (13,20). Friesen and Shebeski (55) estimated the economic loss in cereal crops for Manitoba alone in 1960 to be 29 million bushels of grain valued at 32 million dollars.

Wild oats is a highly persistent weed that is sometimes poorly controlled by cultural and chemical means. Seed dormancy and irregular germination throughout the growing season are the most important features contributing to its persistence (9,10,11,95,118,126,132,133,136). Several preemergence and postemergence herbicides have been in use for selective control of wild oats in various cereal and broad-leaved crops (12,57,61,101,116). However, according to Holroyd (1976), none of the available herbicides satisfied all conditions for an ideal "wild oat" herbicide (cited in 101). In rapeseed, trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine), a preplant soil incorporated herbicide, has been used extensively in Western Canada. The performance of this herbicide, however, has been inconsistent, presumably due to variations in environmental conditions (58,116,123). Barban (4-chloro-2-butynyl-*m*-chlorocarbanilate) and benzoylprop ethyl [ethyl-2-*N*-benzoyl- *N*-(3,4-dichlorophenyl)-*DL*-alanine] are applied postemergence to the weed but they have their limitations in terms of timing of application. Barban is most effective when it is applied at the 2-leaf stage of

wild oats (12,56,116); benzoylprop ethyl is most effective at the 3- to 5-leaf stage of the weed (12,119). Benzoylprop ethyl also has only marginal selectivity towards rapeseed (24). Diclofop methyl [2-(4-(2,4-dichlorophenoxy) phenoxy) propanoic acid] has proved to be very effective against wild oats in rapeseed (12,30), but its efficacy was reduced under unfavourable environmental conditions for plant growth, especially under high temperatures and drought stress conditions (42).

2.5 Biology and Control of Green Foxtail

Green foxtail (*Setaria viridis* (L.) Beauv.) is an annual grass weed of cultivated areas and waste places that has become more prevalent in recent years (2,17,127). Surveys conducted by Alex et al. (2) in the three prairie provinces during 1963-67 indicated that the weed was most frequent in Manitoba, less so in Saskatchewan and least in Alberta.

The recent spread of green foxtail as a weed in Western Canada has been attributed to the widespread use of selective herbicides for the control of wild oats and the broad-leaved weeds. This allowed green foxtail to occupy the niche previously occupied by other weed species (17,108).

Green foxtail has a relatively low competitive ability except in severe infestations (55,108,127). This was attributed in part to greater dependence of green foxtail on

soil temperature and moisture conditions for germination and growth in the spring than most field crops (2,16,17,127). It required relatively high soil temperatures (15 to 35°C) for germination. This gave the crop plants, such as wheat, a competitive advantage over late-germinating green foxtail (16,127). Growth of green foxtail plants also was severely restricted at reduced light intensities such as under a crop canopy (127). The weed did not compete strongly with rapeseed (90,91).

Late germination of green foxtail makes cultural practices mostly ineffective for control (57). Trifluralin has provided good selective control of green foxtail in rapeseed (57). Diclofop methyl also has been recommended for the control of green foxtail in this crop (61).

2.6 Biology and Control of Quackgrass

Quackgrass (*Agropyron repens* (L.) Beauv.) is regarded as one of the worst weeds of arable land in temperate regions of the world (8,102). In Canada, it occurs in all provinces and the Northwest Territories. It is especially common in southeastern Canada, where it was probably introduced from Europe in the 17th century (70,129).

It is a perennial grass weed that spreads by means of seeds and rhizomes; propagation by means of rhizomes is most common in cultivated fields (102,131). The rhizomes generally occur at a shallow depth, 15 to 20 cm, in the

ground and can grow laterally up to 1 m in length (102,129). The seedlings usually are able to initiate rhizomes when they reach the 4-leaf stage of growth with 1 to 2 tillers (130). In general, the plants are most active in sexual reproduction and rhizome formation in the middle of the summer, and in tillering and photosynthesis in spring and autumn (63,129).

Conceivably, every mature rhizome bud is capable of establishing a new plant. However, most buds along an intact rhizome are dormant and do not initiate any growth. Such dormancy is readily broken by cutting the rhizome, but it is quickly reestablished by the first bud that develops on the new rhizome piece (62,70). An increase in the number of aerial shoots was noted when the rhizomes were cut into small pieces (62,129).

Rapid growth coupled with vegetative reproduction, competition for nutrients, moisture and light and possible allelopathic effects on other plant species make quackgrass a troublesome weed in many crop situations (70,129,130).

Periodic and intensive tillage was the only practical control for quackgrass before the introduction of glyphosate, since herbicides that were effective against quackgrass, TCA (trichloroacetic acid) and dalapon (2,2-dichloropropionic acid), were too expensive or too injurious to crop plants (18,35,36,57). Glyphosate has proved to be a very effective herbicide for quackgrass control, but it is non-selective. It must be applied in a

fallow year, or prior to planting or after harvest in the case of application in a cropping year (8,25,39,69). Spring and fall application of glyphosate in Western Canada, however, is not always possible due to the short growing season.

2.7 Structure and Growth of Wild Oat Stems

2.7.1 General morphology and growth

The culm, or stem, of wild oat plants resembles that of oat (*Avena sativa* L.) plants. It consists of several internodes of which the basal internode is the shortest and each successively higher internode is longer than the one below it. The uppermost, or the last, internode (peduncle) is the longest (19,80,97).

Elongation of the internodes usually begins in the fourth internode from the base in oats and proceeds in acropetal succession. Usually three internodes are in the process of elongation at the same time. The basal one of the three may be completing its development when the next one above it is about halfway through the process and the third is beginning to elongate. Panicle differentiation and internode elongation begin at the same time, but the major development in the size of the panicle occurs as the peduncle elongates (19).

2.7.2 Mechanism of stem elongation

The internodes of oat plants exhibit a prolonged intercalary growth that does not occur in organs such as the coleoptile where the dominant component of growth is cell elongation (80). Kaufman et al. (80) demonstrated that during internodal extension in the *Avena* internode, intercalary meristem activity was localized in the base of the internode, with predominant cytokinetic activity occurring in the lower portions of the epidermal and outer ground parenchyma systems. Kaufman and Cassell (79) observed many different stages of mitosis in the cells of the intercalary meristem just above the nodal plate.

The intercalary meristem of oat internodes consists of parallel rows of isodiametric initials which give rise to differentiated elements both above and below the intercalary meristem zone (80). All the tissues of the internode differentiate and develop from the top downward (basipetally). As a consequence, during internode elongation there is meristematic and immature tissue at the base of the internode beneath the mature tissue at the top (19).

Cell division and elongation appear to be overlapping processes during the earliest stages of internodal development in oat plants (80). However, cell division does not continue throughout the growth in length of the internode. The intercalary growth that occurs during the latter two thirds of linear extension of the internode is growth by cell elongation (79,80). The epidermal cells of

Avena sativa were observed to elongate to 20 or 30 times their initial length during extension growth of the internode. The greatest amount of cell elongation occurred in the basal portion of the internode (79). The diameter of the internode increased first by periclinal cell divisions in the internode periphery, in narrow zones just beneath the epidermis, and finally by cell enlargement (19).

Cell lengths vary with the position of the internode. In varieties of winter wheat differing in plant height, an inverse relationship existed between the lengths of parenchyma cells and culm internodes (97). The longest parenchyma cells occurred in the shortest (lowest) internode, and parenchyma cell length was less in each successively higher and longer internode. Generally close agreement between parenchyma and epidermal cell lengths was observed in corresponding internodes. It was suggested that the greater lengths of successively higher internodes of the culm were associated with an increase of equal or greater magnitude in the number of parenchyma and epidermal cells contributing to the length of the internodes (97).

2.7.3 Anatomy

In *Avena* stems, the vascular bundles are generally arranged in two circles. A continuous cylinder of sclerenchyma occurs close to the periphery. The outer smaller bundles are entirely surrounded by this mechanical tissue. The inner ring of vascular bundles is composed of

large vascular bundles surrounded by thin-walled parenchyma cells (ground tissue). The pith often breaks down, except at the nodes (19,82,89).

A section taken from the base of wild oat stem usually appears surrounded by a foliar sheath. The central lacuna may be reduced or completely covered by the parenchyma cells (pith cells) (82). The third, fourth, and higher internodes in *Avena* all have typical collateral vascular bundles. The peripheral and inner rings of vascular bundles are clearly delimited (19).

3. MATERIALS AND METHODS

The three herbicides used in these studies were the emulsifiable concentrate formulations of BAS 9052 OH (184 g/L), TF 1169 (250 g/L) and DOWCO 453 (240 g/L). All treatments with BAS 9052 OH and DOWCO 453 were applied with the adjuvant Atplus 411F[4] (Atkemix Inc., Brantford, Ontario) at 0.5% (v/v) of the spray volume and all treatments with TF 1169 were applied with the adjuvant Agral 90[7] (Chipman Inc.) at 0.1% (v/v) of the spray volume. The grass species tested were green foxtail (*Setaria viridis* (L.) Beauv.), wild oats (*Avena fatua* L.), barley (*Hordeum vulgare* L. cv. Galt) and quackgrass (*Agropyron repens* (L.) Beauv.). The test crop was rapeseed (*Brassica campestris* L. cv. Candle).

3.1 General Procedures

3.1.1 Field experiments

Nine field experiments were conducted during the spring and summer of 1980 and 1981 at two different sites on the Ellerslie Research Station and in a farmer's field 8 km southwest of the Ellerslie Research Station. The experimental area lies in the Black Chernozemic soil zone[8]. Detailed information on the type of soil at each site is presented in Table 1.

---

[4] 17 % polyoxyethylene sorbitan fatty acid in mineral oil.
[7] 90 % alkyl phenol ethylene oxide condensate.
[8] Soils of Canada, Vol. 1, Soil Report, 1977. Can. Dept. of Agric., Ottawa. p. 106.

Table 1. **Information on experimental sites.**

Site	Soil texture	O.M. %	Sand %	Silt %	Clay %	pH
North E.R.S.†	Loam	12.8	39.2	41.2	19.6	6.3
South E.R.S.	Silt loam	10.9	26.0	54.0	20.0	6.4
Farm. field	Silt loam	10.4	34.0	49.0	17.0	6.9

† Ellerslie Research Station.

The plots were arranged in a randomized complete block design with four replicates in all experiments, except one in the farmer's field, where the treatments were replicated only three times. Wild oats (40 kg/ha) and barley (65 kg/ha) were seeded at a depth of 4 cm with a press drill with 15-cm row spacing. Green foxtail (11.1 kg/ha) and rapeseed (6.7 kg/ha) were seeded at a depth of 2 to 3 cm with a V-belt seeder and an experimental plot seeder, respectively, in rows 23 cm apart. The crop rows were seeded from the front to the back of the plots in all experiments requiring a crop. Wild oats, green foxtail, and barley were seeded at right angles to the crop rows.

Herbicide treatments were applied with a bicycle-type plot sprayer fitted with TeeJet 8001 nozzle tips delivering 100 L/ha of spray volume at 276 kPa pressure. The spray angle was adjusted to 45° forward and the nozzle height to 50 cm above the target to achieve thorough and uniform coverage of the grass weeds.

Visual observations on the effectiveness of the herbicides on weeds and on the tolerance of crop plants were

recorded several times through the growing season. Weed plants were rated on a scale of 0 to 9 in order of increasing herbicide injury. A score of 0 indicated no effect while a score of 9 indicated complete kill. The crop plants were rated on a scale of 9 to 0 in order of increasing herbicide injury. A score of 9 indicated no effect while a score of 0 indicated complete kill. At the time of crop maturity, weed culm counts and shoot dry weights and crop yields were recorded from an area of 0.9 m^2 in each plot. The data were subjected to statistical analysis by analysis of variance and the means were compared at the 5 percent level of significance by using Duncan's New Multiple Range Test (43).

3.1.2 Greenhouse experiments

The efficacy and behaviour of BAS 9052 OH, TF 1169 and DOWCO 453 on green foxtail, wild oats, barley and quackgrass were studied under controlled environmental conditions in the greenhouse. The temperature in the growth compartments was maintained at 16 to 20° C during the night and 20 to 24° C during the day. Daylength was extended to 16 hours by providing artificial light from incandescent lamps. The average photon flux density was 300 $\mu E.m^{-2}.s^{-1}$, as measured with a Li-Cor quantum meter'. The relative humidity was 40 to 60 percent.

' Model Li-185; Lambda Inst. Corp., Lincoln, Nebraska.

The plants were grown in a sterilized 2:1:1 mixture of clay-loam, peat and sand in plastic pots, 12 to 15 cm in diameter, and watered daily. For studying the translocation behaviour of the herbicides in quackgrass, rhizome segments were planted in vermiculite[10] in plastic trays. The plants were supplied with Hoagland No. 1 nutrient solution (68) once a week in addition to the regular watering. The experiments were arranged in a randomized complete block or a split plot design with four replicates.

Herbicide treatments were applied with a motor-driven pot sprayer fitted with one travelling nozzle tip (TeeJet E8001) calibrated to deliver 110 L/ha of spray volume at 276 kPa pressure. The height of the nozzle tip was adjusted to 50 cm above the target. For spot treatment of individual plants, a known volume of herbicide emulsion was applied as a single droplet, using a micropipettor. Herbicide emulsions for droplet applications were prepared in the same way as for spray applications, by mixing a known volume of the formulated herbicide, corresponding to the rate to be applied, in 250 ml water. Atplus 411F at 0.5% (v/v) was added to the emulsions of BAS 9052 OH or DOWCO 453. Agral 90 at 0.1% (v/v) was added to the emulsions of TF 1169. The volume of herbicide emulsion to be applied to the plants was determined by calculating the surface area of the aboveground parts of the plant, using graph paper, then

---

[10] Horticultural, W.R. Grace & Co. of Canada Ltd., Ajax, Ontario.

calculating the volume of herbicide solution that would be intercepted by this area when sprayed at the rate of 110 L/ha. The volume of spray solution intercepted by the shoot was determined also by spraying the plants with a dye (Aldrich, 21074-9, Acid Red 4; 2 g/L) solution, using the pot sprayer. The plants sprayed with the dye solution were washed in 25 ml distilled water and the absorbance of the solutions was measured with a spectrophotometer (Beckman model 25) at 508 nm. The volume of spray solution thus intercepted by each plant was calculated from a standard curve, established for absorbance vs ul of dye solution in 25 ml distilled water.

Treated plants were clipped at soil level 15 days after treatment, dried at 60 to 70° C for 48 hours, and weighed. The means were compared at the 5 percent level of significance by using Duncan's New Multiple Range Test or L.S.D. (Least Significant Diffrence) values.

3.2 Efficacy of the Herbicides for Grass Weed Control

3.2.1 Control of annual grasses in the field

3.2.1.1 Wild oat and volunteer barley control in rapeseed

The control of wild oats and volunteer barley in rapeseed was evaluated in experiments in 1980 and 1981 on the south side of the Ellerslie Research Station. In both years, 24 rows of wild oats were seeded across the front 3.6

m and barley was seeded across the back 1.8 m of each 1.8 x 5.4 m plot. Rapeseed was seeded from the front to the back in the entire plot. In 1980, BAS 9052 OH at three rates was applied at the 2-, 3- or 5-leaf stage of wild oats while in 1981, BAS 9052 OH and TF 1169 each at three rates were applied at the 2- or 5-leaf stage of the weed.

In both years, wild oats and barley were harvested from an area of 0.9 m^2 in their respective regions in each plot. Rapeseed was harvested from an equal area in the region cross-seeded with wild oats. Data were obtained on weed culm counts and shoot dry weights and rapeseed yields.

3.2.1.2 Green foxtail control in rapeseed

One experiment each in 1980 and 1981 was conducted on the south side of the Ellerslie Research Station to evaluate the control of green foxtail in rapeseed with BAS 9052 OH and TF 1169. In both years, 16 rows of green foxtail were seeded at right angles to 8 rows of rapeseed in each 1.8 X 3.6 m plot. In 1980, BAS 9052 OH at three rates and TF 1169 at one rate were applied at the 2- or 4-leaf stage of green foxtail. In 1981, BAS 9052 OH and TF 1169 at three rates each were applied at the 2- or 4-leaf stage of the weed. The experiment in 1981 also included a combination of BAS 9052 OH and TF 1169.

In both years, green foxtail and rapeseed were harvested from an area of 0.9 m^2 in each plot. Data were obtained on green foxtail shoot dry weights and rapeseed

yields.

3.2.1.3 Annual grass weed control without crop and in crop

The influence of crop competition on the efficacy of BAS 9052 OH, TF 1169, and DOWCO 453 for annual grass weed control was examined in an experiment on the north side of the Ellerslie Research Station in 1981. The plot size in this experiment was 3.6 X 5.4 m. Green foxtail was seeded across the front 1.8 m, wild oats in the middle 1.8 m, and barley in the back 1.8 m of each plot. Rapeseed was seeded in rows from the front to the back in the left half (1.8 m) of each plot. The right halves (1.8 m) of the plots contained the weeds but no crop. Herbicide treatments consisted of three rates each of BAS 9052 OH, TF 1169, and DOWCO 453 and also three different combinations of BAS 9052 OH and TF 1169. All treatments were applied when the wild oat plants were in the 3-leaf stage. An overspray with cyanazine[11] plus MCPA-K[12] (1:2 w/w) at 0.8 kg/ha was applied in the plot part without crop, to control broad-leaved weeds, one month after test herbicide applications. Precautions were taken to prevent any spray drift of the herbicide from reaching the crop plants by using wind shields during spraying. Canada thistle plants were treated individually with glyphosate (35.6 g/L) solution, with a herbicide glove.

---

[11] 2-[[4-chloro-6-(ethylamino)-S-triazin-2-yl] amino]-2-methylpropionitrile

[12] Potassium salt of MCPA.

At the time of maturity of the crop, green foxtail, wild oats, and barley were harvested from an area of 0.9 m^2 in both the plot part with rapeseed and the plot part without crop. Shoot dry weights were determined for all three weeds and culm counts also were made for wild oats and barley. Rapeseed yield data were obtained from a 0.9-m^2 area cross-seeded with wild oats.

3.2.2 Effect on the growth of wild oats, green foxtail and barley

The effect of BAS 9052 OH, TF 1169, and DOWCO 453 on growth of wild oats, green foxtail, and barley was evaluated also in greenhouse experiments. Each weed species was grown in 12-cm diameter plastic pots filled with soil mix. Four wild oat or barley plants or six green foxtail plants were grown in each pot. Experiments were conducted separately for each weed species. Each herbicide was sprayed at four rates at the 2- or 4-leaf stage of the weed in each experiment. Visual observations were recorded on the development of injury symptoms on the weeds until 15 days after treatment, when the plants were clipped at soil level and shoot dry weights per pot were determined. Each experiment was conducted twice.

3.2.3 Quackgrass control in the field

Two experiments were initiated in 1981 to evaluate the efficacy of the herbicides for the control of quackgrass grown from planted rhizome segments and in an established stand.

3.2.3.1 Control of quackgrass grown from planted rhizomes

The experiment was established on the south side of the Ellerslie Research Station. Quackgrass rhizomes were collected in May, 1981 from a heavily infested field. Segments 3 to 5 cm long, with one or two nodes each, were planted on May 12 to May 15, 8 cm apart in rows spaced 30 cm apart. Plot size was 1.8 X 3.6 m, with six rows per plot. Treatments consisting of three different rates of BAS 9052 OH, TF 1169, and DOWCO 453 were applied on June 18, when the quackgrass plants were in the 3- to 4-leaf stage. A treatment with glyphosate at 1 kg/ha was also included. All plots were oversprayed on July 10 with chlorsulfuron[13] at 80 g/ha to control broad-leaved weeds. Wild oats and volunteer barley were removed by hand. Quackgrass culm counts and shoot dry weights were obtained from a 0.9-m^2 area in each plot on August 20. The plots also were rated visually in the spring of 1982 to assess the regrowth of quackgrass.

In 1982, the plots were cross-disced and 'Galt' barley (65 kg/ha) was seeded across the back half of each plot on May 18 to examine the effect of any herbicide residue in the

---

[13] 2-chloro-*N*-[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino-carbonyl]benzenesulfonamide.

soil from the previous year's applications on barley growth and also to examine the effect of crop competition on quackgrass regrowth. The plots were rated visually to assess the regrowth of quackgrass and any injury to barley.

3.2.3.2 Control of established quackgrass

The experiment was laid out in a farmer's field situated 8 km southwest of the Ellerslie Research Station. The field was heavily infested with quackgrass. The area was cross-disced in the spring and the plots were rototilled twice to a depth of 5 to 10 cm in order to obtain a uniform weed stand. The plots were 1.8 m wide and 6 m long. There were three replicates. Treatments consisting of three different rates each of BAS 9052 OH and TF 1169, and also two different combinations of BAS 9052 OH and TF 1169 were applied on June 25, when the plants were in the 3- to 4-leaf stage. A treatment with glyphosate at 1 kg/ha was also included. All plots were oversprayed on July 10 with 80 g/ha of chlorsulfuron to control broad-leaved weeds. Shoot dry weight data were obtained from two 0.9-m^2 areas in each plot on August 20. Visual observations also were recorded to assess the regrowth of quackgrass in the spring of next year (1982).

3.2.4 Effect on the growth of quackgrass plants

Quackgrass rhizomes, collected from a heavily infested field in June, 1981, were planted in 15-cm diameter plastic pots in the greenhouse. Rhizomes from these pots were used later to study the effect of the herbicides on the growth of quackgrass plants.

Segments 2 to 3 cm in length, with one node each, were planted afresh in 15-cm diameter plastic pots. Five rhizome segments were planted in each pot. Treatments consisting of four different rates each of BAS 9052 OH, TF 1169, and DOWCO 453 were applied at the 2- to 3- or 4- to 5-leaf stage of the plants, using the pot sprayer described in section 3.1.2. The number of rhizome segments sprouted in each pot was noted just before spraying. Visual observations on the development of injury symptoms were recorded until 15 days after treatment, when the plants were clipped at soil level and their shoot dry weights were determined. The dry weights were converted to mg per plant per pot.

To study the viability of quackgrass rhizomes after herbicide treatment, rhizome segments in the above experiment were allowed to resprout after clipping the shoots. Regrowth from these rhizome segments was assessed 15 days after clipping by counting the rhizome segments giving rise to new shoots, and determining the shoot dry weight per pot. The experiment was repeated once.

3.3 Morphological and Histological Effects

3.3.1 Plant material

Wild oat plants from seeds of uniform size were grown in the greenhouse in 12-cm diameter plastic pots. Only two plants were grown in each pot. Experiments were conducted separately for BAS 9052 OH, TF 1169, and DOWCO 453. In each experiment, two different rates of the herbicide were applied to plants at the 5-leaf stage. The fourth internode (the internode between the points of insertion of the fourth and fifth leaves) of these plants was 1 to 2 mm in length. Herbicide applications were made with the pot sprayer described in section 3.1.2. Observations on morphological and histological effects were recorded 0, 2, 5, 9, and 14 days after treatment. Histological examinations were conducted only on the fourth internode of wild oat stems.

The treatments were replicated eight times, each plant representing one replication. The pots were arranged in a split plot design, with days of harvesting as the main plots and herbicide treatments as the sub plots.

3.3.2 Histological procedure

For histological studies, a 1- to 2-mm-long stem segment was excised from just above the fourth nodal plate (the point of insertion of the fourth leaf), and fixed in formalin : acetic acid : ethanol (50%), 1:1:18 (v/v), for 24 hours. The segments were dehydrated by passing them through

a t-butanol series (50, 70, 85, 95 and 100%) as described by Jensen (77). The series consisted of mixtures of t-butanol, ethanol and water; the ethanol and water being replaced by t-butanol in the higher members of the series. The segments were left in each member of the series for 4 to 8 hours, then finally transferred to 100% t-butanol for 12 to 24 hours. The dehydrated segments were put in glass vials containing solid paraplast'⁴. The vials were kept in an oven at 55 to 60° C for 24 to 48 hours to allow infiltration of paraplast into the tissue segments. Several changes of fresh molten paraplast were made before the segments were finally embedded in the medium into small rectangular blocks, using paper boats. Tissue sections, 5 µm thick, were cut on a hand-operated rotary microtome fitted with a steel knife. The ribbons of paraffin sections were floated on a thin layer of 4% formalin on glass slides treated with a thin film of Haupt's adhesive'⁵. The slides were warmed on a hotplate at 35° C before draining off the excess formalin, and allowed to dry.

For staining of the tissue sections, the method described by Jensen (77) and Berlyn and Miksche (15) was followed. Tissue sections affixed to slides were put in xylene in Coplin jars to dissolve the paraffin, then passed

---

'⁴A tissue-embedding medium consisting of purified paraffin and plastic polymers; Sherwood Medical Industries, St. Louis, Missouri.

'⁵1 g gelatin was added in 100 ml water at 90° C. The mixture was cooled to 30° C and 15 ml glycerine was added. Phenol (2 g) was added as preservative.

through a hydration series consisting of a decreasing concentration of ethanol (absolute, 95%, 80%, 70% and 50%). The sections were stained in 0.5% safranin O (C.I. 50240; Fisher Scientific Company, New Jersey) in distilled water and counterstained in 0.5% fast green FCF (C.I. 42053; Fisher Scientific Company, New Jersey) in 95% ethanol. The sections were mounted in Canada balsam (neutral-filtered; Fisher Scientific Company, New Jersey).

3.3.3 Observations recorded

Morphological observations were recorded on total culm length (from the base of the plant to the base of the panicle) and the length of the second, third, and fourth internode. Histological observations were recorded on both transverse and longitudinal sections of the stem taken from near the base of the fourth internode. Four plants in each treatment replication were used for transverse sectioning and the other four for longitudinal sectioning. The transverse sections were used to record observations on culm diameter, vascular bundle diameter and cell diameter in the cortex between the vascular bundles (Figure Ia). The longitudinal sections were used to determine the width of cells in the ground parenchyma and the length of cells in the cortex as well as in the ground parenchyma (Figure Ib).

Culm diameter and cell width were measured at 35X magnification while all other observations were made at 100X magnification, using an ocular micrometer.

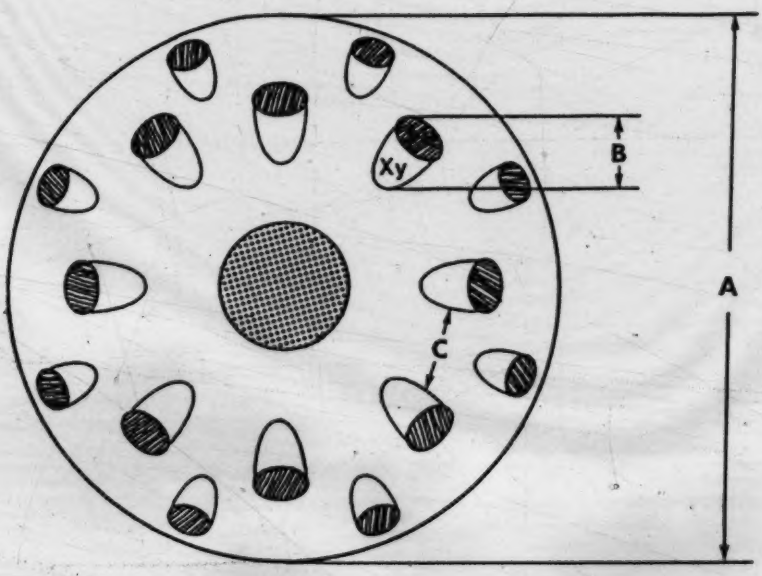


Figure Ia. Diagrammatic representation of a transverse section of wild oat stem.

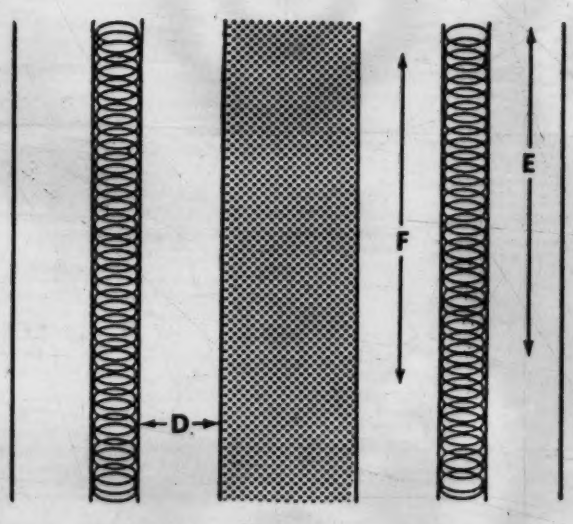


Figure Ib. Diagrammatic representation of a longitudinal section of wild oat stem.

A = Culm diameter
B = Vascular bundle diameter
C = Region of cell diameter determination
D = Region of cell width determination
E & F = Regions of cell length determination

The ocular micrometer was calibrated using a stage micrometer (American Optical Company, Buffalo, N.Y.). Each division on the ocular micrometer corresponded to 14.8 µm at 35X magnification and 5.3 µm at 100X magnification.

3.4 Translocation Behaviour

3.4.1 Site of application of herbicides on grass weeds

Six experiments, three each on wild oats and green foxtail, were conducted to examine the effectiveness of BAS 9052 OH, TF 1169, and DOWCO 453 when applied at different sites on the plants. Separate experiments were conducted for each herbicide on each weed species. Four plants per pot were grown in the greenhouse. Wild oats were treated at the 3-leaf stage while green foxtail was treated at the 4-leaf stage of growth.

Herbicide treatments were applied as single droplets using a micropipettor at four different sites on separate wild oat plants and at three different sites on separate green foxtail plants. Three concentrations of each herbicide corresponding to 0.01, 0.03, and 0.05 kg/ha rates of BAS 9052 OH or TF 1169 and 0.005, 0.01, and 0.03 kg/ha rates of DOWCO 453 were applied as single 5- or 8-µl droplets at the tip, middle or base of the second leaf or between the sheath of the second leaf and the stem of wild oat plants. To apply the herbicide treatment between the leaf sheath and the

stem, the sheath was gently separated from the stem at the ligule end to make space for herbicide application. The herbicide emulsion in the tip, middle or basal treatment of the second leaf was prevented from spreading by keeping the leaf horizontal on a wooden plank until the droplet was dry. The emulsion applied between the leaf sheath and the stem was allowed to run down to the base of the sheath. In the case of green foxtail, three concentrations of the herbicides corresponding to 0.005, 0.01, and 0.03 kg/ha rates of BAS 9052 OH or DOWCO 453, and 0.01, 0.03, and 0.05 kg/ha rates of TF 1169, were applied at the tip, middle or base of the third leaf only. The volume of herbicide emulsion applied as single droplets on individual plants was determined according to the methods described in section 3.1.2.

The treatments were replicated four times, and each replicate consisted of four plants. The plants were harvested 15 days after treatment and shoot dry weights were recorded. The experiments were conducted twice for each herbicide and each weed species.

3.4.2 Mutilation experiments

Wild oat plants were grown in the greenhouse, four plants per pot. Individual wild oat plants were treated at the 3-leaf stage. Two concentrations of the herbicides corresponding to 0.02 and 0.05 kg/ha rates of BAS 9052 OH or DOWCO 453 and 0.05 and 0.10 kg/ha rates of TF 1169 were

applied as single 5- or 8-µl droplets on the adaxial surface of the middle of the second leaf according to the method described in sections 3.1.2 and 3.4.1.

At different intervals after herbicide application, the treated leaves were removed from the plants by cutting them off near the base of the leaf blades. The treatments were replicated four times and each replicate consisted of four plants. The plants were harvested 15 days after treatment and shoot dry weights were recorded. Experiments were conducted separately for each herbicide and repeated in all cases.

3.4.3 Viability of quackgrass rhizomes

Quackgrass rhizomes were collected from plastic pots previously planted with rhizomes obtained from the field. Rhizome segments, 20 to 30 cm in length, each consisting of 10 nodes, were planted in vermiculite in plastic trays in the greenhouse. Each tray contained four rhizome segments. Only one shoot from the proximal end node of each rhizome segment was allowed to develop. The shoots arising from other nodes on the rhizome segments were clipped off. When the plants reached the 2- to 3- or 4- to 5-leaf stage, BAS 9052 OH, TF 1169 or DOWCO 453, each at three rates, was applied using the pot sprayer. The herbicide spray was prevented from reaching the vermiculite in the trays by covering it with paper towels, thus exposing only the shoots. The treatments were replicated four times, each

rhizome segment in the trays representing one replication. The plants were harvested 15 days after treatment and shoot dry weights were recorded.

The rhizome segments were removed from the vermiculite, washed in running tap water, and cut into one-node sections. These sections were planted separately in 2.5 X 5 cm plastic cups filled with vermiculite. The sequence of nodes from each rhizome segment was maintained while planting them in the plastic cups. The proximal end node of the segment, which gave rise to the shoot, was designated as number 1. The number of nodes sprouted in each replication and the shoot dry weights were recorded 4 weeks after planting.

The mean number of nodes sprouted on each rhizome segment was transformed using an $\arcsin \sqrt{\text{percentage}}$ transformation. The transformed data were analyzed using factorial analysis with factor A as the growth stages and factor B as the herbicide treatments. The means were compared at the 5 percent level of significance using L.S.D. values.

3.5 Herbicide Mixtures

Two experiments, one each in 1980 and 1981, were conducted in the field to study the compatibility of BAS 9052 OH with other herbicides for wild oat control and the compatibility of BAS 9052 OH, TF 1169, and DOWCO 453 with DOWCO 290.

3.5.1 BAS 9052 OH mixtures with other wild oat herbicides

The experiment was conducted on the south side of the Ellerslie Research Station in 1980. Wild oats were seeded across while rapeseed was seeded from the front to the back in 1.8 x 3.6 m plots. Herbicide treatments consisted of three rates of BAS 9052 OH, one rate each of barban, diclofop methyl, and benzoylprop ethyl applied alone, and mixtures of BAS 9052 OH, at low rates, with barban, diclofop methyl or benzoylprop ethyl, also at low rates. Barban sprayed alone was applied at the 2-leaf stage. All other treatments were applied at the 3-leaf stage of wild oats. At the end of the season, weed culm counts and shoot dry weights and rapeseed yields were determined from an area of 0.9 m^2 in each plot.

3.5.2 Herbicide mixtures with DOWCO 290

The experiment was conducted on the north side of the Ellerslie Research Station in 1981. Green foxtail, wild oats, and barley were seeded across in 1.8 m strips in each 3.6 x 5.4 m plot. Similar to the arrangement described in section 3.2.1.3, rapeseed was seeded from the front to the back in the left half of the plots only. Herbicide treatments consisting of mixtures of BAS 9052 OH, TF 1169, DOWCO 453, and diclofop methyl with DOWCO 290 were applied at the 3-leaf stage of wild oats. A treatment with trifluralin was applied before seeding the weeds and the crop, and incorporated to a depth of 5 to 7 cm with a

rototiller. Green foxtail, wild oats, and barley were harvested from an area of 0.9 m^2 in both the plot part with rapeseed and the plot part without crop. Weed culm counts and shoot dry weights were determined for wild oats and barley while only shoot dry weights were determined for green foxtail. Rapeseed yields were determined from an area of 0.9 m^2 in the plot part cross-seeded with wild oats.

4. RESULTS AND DISCUSSION

4.1 Annual Grass Weed Control in Rapeseed

In 1981, all treatments with BAS 9052 OH and TF 1169 provided excellent control of wild oats at the 2- and 5-leaf stages of growth (Table 2). BAS 9052 OH at the lowest rate (0.15 kg/ha) was less effective on volunteer barley when applied at the later (5-leaf) growth stage. Rapeseed plants were not affected by any of the treatments. Although mean rapeseed yields in all herbicide-treated plots were numerically higher than in the weedy check, the differences were not statistically significant.

Results from an experiment conducted in 1980 also indicated that wild oat control with BAS 9052 OH was excellent at all (2-, 3-, and 5-leaf) growth stages. However, contrary to the results obtained in 1981, volunteer barley showed more resistance to low rates of BAS 9052 OH at the earlier growth stages than at the 5-leaf stage (Appendix Table I).

The discrepancy in results from the two years of experiments may have been due to the effects of environmental factors such as moisture and temperature on the growth of weed plants and the behaviour of the herbicides in plants. Weather data from our experimental sites indicated that lower minimum and maximum temperatures at the time of treatment and shortly thereafter corresponded

with poor weed control.

Table 2. **Wild oat and volunteer barley control in rapeseed (1981).**

Treatment†	Rate kg/ha	Wild oats Score Aug 8	Wild oats Culms /m²‡	Wild oats D.W. g/m²‡	Vol. barley Score Aug 8	Vol. barley Culms /m²‡	Vol. barley D.W. g/m²‡
Weedy Check	0	0	274 a	131 a	0	259 a	558 a
BAS 9052 OH 2 LS 0.15	9	0	0 b	0 b	9	0 c	0 c
BAS 9052 OH 5 LS 0.15	9	9	4 b	1 b	7	69 b	64 b
BAS 9052 OH 2 LS 0.25	9	9	0 b	0 b	9	0 c	0 c
BAS 9052 OH 5 LS 0.25	9	9	0 b	0 b	8	15 c	12 c
BAS 9052 OH 2 LS 0.40	9	9	0 b	0 b	9	0 c	0 c
BAS 9052 OH 5 LS 0.40	9	9	0 b	0 b	9	0 c	0 c
TF 1169 2 LS 0.25	9	9	0 b	0 b	9	0 c	0 c
TF 1169 5 LS 0.25	9	9	0 b	0 b	8	29 bc	40 bc
TF 1169 2 LS 0.35	9	9	0 b	0 b	9	0 c	0 c
TF 1169 5 LS 0.35	9	9	1 b	1 b	9	0 c	0 c
TF 1169 2 LS 0.45	9	9	0 b	0 b	9	0 c	0 c
TF 1169 5 LS 0.45	9	9	5 b	2 b	9	0 c	0 c

†LS refers to leaf stage of wild oats at spray time. Volunteer barley was at the 4- or 6-leaf stage at the time of treatment.
‡Means in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

In 1980, the minimum and maximum temperatures were 1.5 and 12°C, respectively, when the treatments were applied at the 2-leaf stage, and 9 and 25°C, respectively, when the treatments were applied at the 5-leaf stage of wild oats (Appendix Table IV). In 1981, the minimum and maximum temperatures were 10.5 and 21.1°C, respectively, when the treatments were applied at the 2-leaf stage, and 3.3 and 17.6°C, respectively, when the treatments were applied at the 5-leaf stage of wild oats (Appendix Table V). All

treatments were applied early in the morning. Reports in the literature have indicated that factors such as low temperature, low relative humidity and drought stress reduced the efficacy of BAS 9052 OH and TF 1169 on some grass weeds (28,84,87,109).

All herbicide treatments with BAS 9052 OH and TF 1169 reduced the dry weight of green foxtail at both 2- and 4-leaf stages (Table 3).

Table 3. **Green foxtail control in rapeseed (1981).**

Treatment†		Rate kg/ha	Green foxtail		Rape
			Score Aug 8	Dry wt. g/m²‡	Yield g/m²‡
Weedy check			0	32 a	209
BAS 9052 OH	2 LS	0.10	8	2 b	229
BAS 9052 OH	5 LS	0.10	9	1 b	197
BAS 9052 OH	2 LS	0.15	9	1 b	246
BAS 9052 OH	5 LS	0.15	9	1 b	194
BAS 9052 OH	2 LS	0.25	9	1 b	252
BAS 9052 OH	5 LS	0.25	9	1 b	210
TF 1169	2 LS	0.20	7	1 b	198
TF 1169	5 LS	0.20	7	4 b	185
TF 1169	2 LS	0.30	8	2 b	219
TF 1169	5 LS	0.30	8	4 b	193
TF 1169	2 LS	0.45	9	1 b	219
TF 1169	5 LS	0.45	9	1 b	229
BAS 9052+TF1169	2 LS	0.10+0.20	9	1 b	219
BAS 9052+TF1169	5 LS	0.10+0.20	9	0 b	251

†LS refers to leaf stage of green foxtail at spray time.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Visual observations indicated that, in general, treatments with BAS 9052 OH provided better green foxtail control than

treatments with TF 1169. Mixtures of BAS 9052 OH and TF 1169 at the lowest rates were very effective in controlling green foxtail. None of the treatments increased rapeseed yields significantly over the weedy check. No injury to rapeseed plants was observed from any of the treatments.

Results of a similar experiment in 1980 indicated that green foxtail control with BAS 9052 OH (0.03 to 0.15 kg/ha) or TF 1169 (0.35 kg/ha) was better at the 2-leaf stage than at the 4-leaf stage. At the advanced growth stage, green foxtail showed more resistance to TF 1169 than to BAS 9052 OH (Appendix Table II).

In 1980, treatments with BAS 9052 OH and TF 1169 applied at the 4-leaf stage of green foxtail resulted in some injury to rapeseed plants and a thinner stand. Consequently, green foxtail plants that survived herbicide treatments recovered and grew vigorously in the absence of strong competition from the crop. No injury to crop plants was observed in 1981 and all herbicide treatments provided effective control at both 2- and 4-leaf stages.

4.2 Annual Grass Weed Control Without Crop and in Crop

All herbicide treatments reduced the number and dry weight of wild oat culms without crop and in crop significantly (Table 4). Visual observations indicated that, in general, wild oat control in crop was better than without crop, especially at low herbicide rates. In weedy check

plots, competition from rapeseed reduced the number and dry weight of wild oat culms by about 19% and 48%, respectively. In the absence of crop competition, plants that survived herbicide treatments recovered well after initial suppression and grew normally to maturity later in the season. Mixtures of BAS 9052 OH and TF 1169 provided excellent control of wild oats in both situations.

Table 4. Control of wild oats without crop and in crop.

		Wild oats						
		Without crop			In crop			
Treatment†	Rate kg/ha	Score Aug18	Culms /m²‡	D.W. g/m²‡	Culms /m²‡	D.W. g/m²‡		Rape Yield g/m²‡
Weedy check		0	547 a	709 a	443 a	368 a		142
BAS 9052 OH	0.15	7	43 b	56 b	3 b	3 b		255
BAS 9052 OH	0.25	9	3 b	6 b	0 b	0 b		236
BAS 9052 OH	0.35	9	0 b	0 b	0 b	0 b		233
TF 1169	0.25	8	47 b	55 b	0 b	0 b		201
TF 1169	0.35	7	39 b	57 b	0 b	0 b		208
TF 1169	0.45	9	7 b	7 b	0 b	0 b		200
BAS9052+TF1169	0.15+0.15	9	1 b	1 b	0 b	0 b		254
BAS9052+TF1169	0.10+0.20	9	4 b	3 b	0 b	0 b		210
BAS9052+TF1169	0.20+0.10	9	4 b	5 b	0 b	0 b		204
DOWCO 453	0.07	7	44 b	62 b	1 b	1 b		227
DOWCO 453	0.15	9	1 b	1 b	0 b	0 b		256
DOWCO 453	0.35	9	0 b	0 b	0 b	0 b		198

†Atplus 411F at 0.25% and Agral 90 at 0.05% (v/v) of the final spray volume were added to the mixtures of BAS 9052 OH and TF 1169.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Rapeseed plants were not injured by any of the treatments.

Although rapeseed yields were numerically higher in the herbicide-treated plots than in the weedy check, the differences were not statistically significant (Table 4).

Table 5. **Control of green foxtail without crop and in crop.**

Treatment†	Rate kg/ha	Green foxtail		
		Without crop		In crop
		Score Aug 18	Dry wt. g/m²‡	Dry wt. g/m²‡
Weedy check		0	526 a	143 a
BAS 9052 OH	0.15	6	164 b-e	7 b
BAS 9052 OH	0.25	8	56 de	3 b
BAS 9052 OH	0.35	8	70 de	1 b
TF 1169	0.25	4	290 b	6 b
TF 1169	0.35	5	249 bc	7 b
TF 1169	0.45	7	117 c-e	8 b
BAS9052+TF1169	0.15+0.15	7	84 de	1 b
BAS9052+TF1169	0.10+0.20	6	197 b-d	1 b
BAS9052+TF1169	0.20+0.10	8	48 de	2 b
DOWCO 453	0.07	6	124 c-e	3 b
DOWCO 453	0.15	7	61 de	0 b
DOWCO 453	0.35	9	11 e	0 b

†Atplus 411F at 0.25% and Agral 90 at 0.05% (v/v) of the final spray volume were added to the mixtures of BAS 9052 OH and TF 1169.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Control of green foxtail in crop, on the basis of dry weight data, was excellent with all herbicide treatments (Table 5). Competition from the crop reduced the dry weight of green foxtail in the weedy check by more than 70%. Dry weights of green foxtail without crop were not significantly

different in most instances due to high variability in the data. Visual observations indicated that control in the absence of crop competition was only poor to fair with some herbicide treatments. TF 1169 at lower rates (0.25 to 0.35 kg/ha) especially was less effective in controlling green foxtail without crop. The lowest rate of BAS 9052 OH alone or in mixture with TF 1169, and the lowest rate of DOWCO 453 also provided unsatisfactory control of green foxtail without crop.

Volunteer barley control was excellent with all herbicide treatments, both without crop and in crop (Table 6). In the weedy check, competition from the crop reduced the number and dry weight of barley culms by only 22% and 17%, respectively. Visual observations indicated that plants that survived herbicide treatments recovered well after initial suppression in the absence of crop competition, but remained stunted under crop competition.

In general, grass weed control with the herbicide treatments was better when the weeds were growing with rapeseed than when they were growing without this crop. Competition from the crop reduced the growth of weed plants and may have affected their recovery after herbicide application. Green foxtail was most sensitive to competition from rapeseed. Thus, competition from the crop could improve the efficacy of BAS 9052 OH, TF 1169, and DOWCO 453 on grasses, especially at low rates of herbicide application.

Table 6. Control of volunteer barley without crop and in crop.

Treatment†	Rate kg/ha	Volunteer barley				
		Without crop			In crop	
		Score Aug 18	Culms /m²‡	D.W. g/m²‡	Culms /m²‡	D.W. g/m²‡
Weedy check		0	400 a	864 a	310 a	716 a
BAS 9052 OH	0.15	8	13 b	23 b	11 b	10 b
BAS 9052 OH	0.25	9	1 b	1 b	0 b	0 b
BAS 9052 OH	0.35	9	0 b	0 b	0 b	0 b
TF 1169	0.25	9	2 b	8 b	1 b	1 b
TF 1169	0.35	9	0 b	0 b	0 b	0 b
TF 1169	0.45	9	0 b	0 b	0 b	0 b
BAS9052+TF1169	0.15+0.15	9	0 b	0 b	0 b	0 b
BAS9052+TF1169	0.10+0.20	9	0 b	0 b	0 b	0 b
BAS9052+TF1169	0.20+0.10	9	0 b	0 b	0 b	0 b
DOWCO 453	0.07	8	3 b	9 b	5 b	5 b
DOWCO 453	0.15	9	0 b	0 b	0 b	0 b
DOWCO 453	0.35	9	0 b	0 b	0 b	0 b

†Atplus 411F at 0.25% and Agral 90 at 0.05% (v/v) of the final spray volume were added to the of the mixture of BAS 9052 OH and TF 1169.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

My results were similar to those reported by O'Sullivan et al. (100) and Sharma and Vanden Born (120) from their experiments with some herbicides for wild oat control in wheat or barley. The poor control of green foxtail in the absence of crop might have been due to late germination of some green foxtail seeds in addition to recovery of some plants after herbicide application. The soil was dry to a depth of about 2 cm when green foxtail was seeded, and

rainfall was delayed. Increasing the rates of the herbicide treatments improved green foxtail control without crop considerably, possibly due to herbicide activity through the soil on later germinating plants. Some soil activity of BAS 9052 OH (73), TF 1169 (4,32,123), and DOWCO 453 (5) at high rates of application has been observed on some grass weeds.

Rapeseed showed a high level of tolerance to BAS 9052 OH, TF 1169, and DOWCO 453 in all except one instance. However, control of wild oats or green foxtail in crop did not result in significant increases in crop yield. It has been reported that wild oats are a strong competitor with rapeseed and can reduce the yield of the crop considerably (40). In our experiments, rapeseed yields, although numerically higher in the herbicide-treated plots than in the weedy check, were not significantly different due to high variability in the data. Uneven germination in the spring and shattering losses during harvesting may have contributed to variability in rapeseed yields. Green foxtail control did not increase the yield of rapeseed, possibly because green foxtail does not compete strongly with the crop (90,91).

4.3 Effect of the Herbicides on Growth of Annual Grasses

4.3.1 Injury symptoms

Symptoms of herbicide injury on wild oats, green foxtail, and barley did not become visible until 3 days after treatment with BAS 9052 OH or DOWCO 453 and 4 days after treatment with TF 1169. During this period, the growth of the plants continued as the youngest leaf elongated for some time after treatment. The first visible injury symptoms were inhibition of growth and development of chlorosis near the base of the youngest leaf. This chlorosis on the youngest leaf then progressed towards the leaf tip. A shrivelling of the tissue occurred near the base of the leaf, from which point the leaf blade drooped down and turned completely chlorotic. These shrivelling symptoms were particularly pronounced on green foxtail. Chlorosis then spread progressively towards the older leaves, starting at the base and progressing towards the tip of the leaf blades. The oldest leaf was the last to be affected. Leaf chlorosis was most prominent on barley and least on green foxtail. In addition to leaf chlorosis, necrosis appeared near the base of the stem. The stem turned brown at this point and was unable to support the plant. Death was complete within 2 to 3 weeks after treatment. BAS 9052 OH and DOWCO 453 caused more chlorosis on the leaves and earlier death of plants than TF 1169.

At low rates of the herbicides, chlorosis was associated with curling and crinkling of the young tissue, possibly as a result of irregular growth that continued for a longer period after these treatments than after application at higher rates. At high rates, injury symptoms were enhanced and death occurred quickly.

4.3.2 Dry weight reductions

All three herbicides reduced the dry weight of wild oat, green foxtail, and barley shoots determined 15 days after treatment. Four rates each of BAS 9052 OH, TF 1169, and DOWCO 453 were applied at the 2- or 4-leaf stage of the weeds in the greenhouse. From the dose-response curves (Figures 1 to 3), obtained by plotting increase in dry weight of treated plants, after treatment, as a percentage of the corresponding increase in dry weight of control plants, the rates that inhibited the increase in dry weight of plants by 50% (GR_{50} values) were calculated (Table 7), by the method of least squares. These GR_{50} values were used to compare the efficacy of the herbicides on wild oats, green foxtail, and barley at two different stages of growth.

The GR_{50} values indicated that wild oats were equally susceptible to BAS 9052 OH, TF 1169, or DOWCO 453 at the 2-leaf stage of growth (Table 7). The plants were significantly less susceptible to BAS 9052 OH at the 4-leaf stage than at the 2-leaf stage.

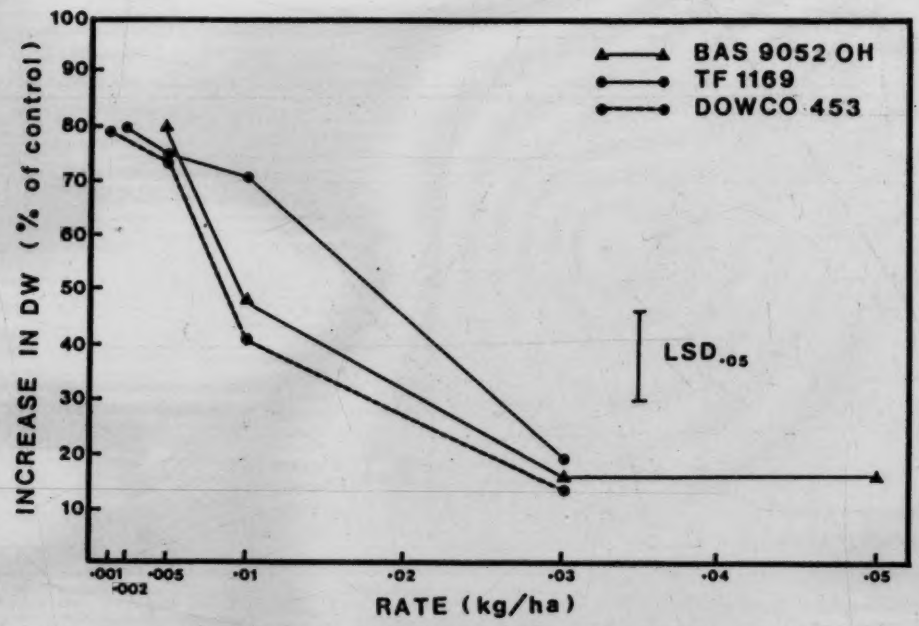


Figure 1a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of wild oat plants, 15 days after treatment at the 2-leaf stage.

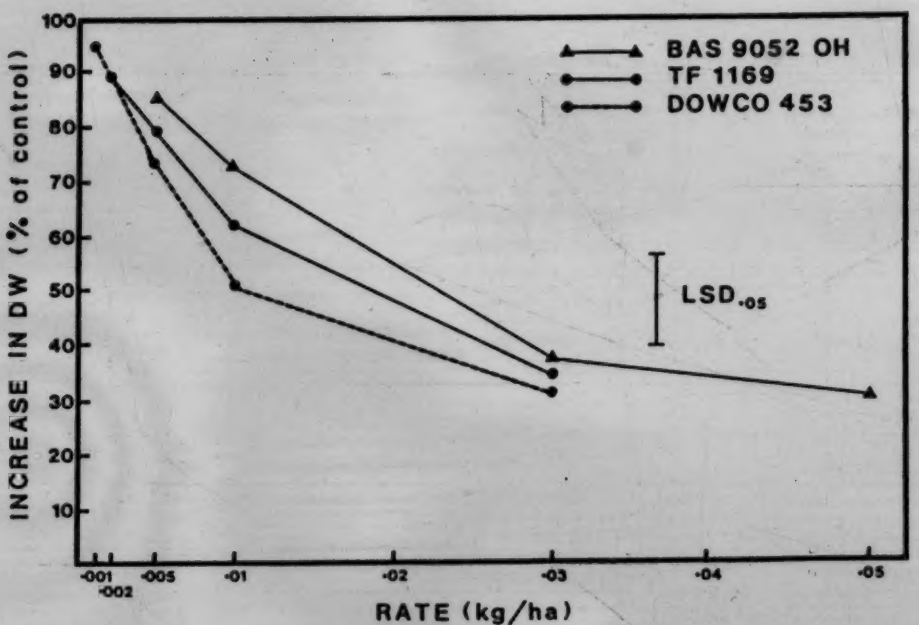


Figure 1b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of wild oat plants, 15 days after treatment at the 4-leaf stage.

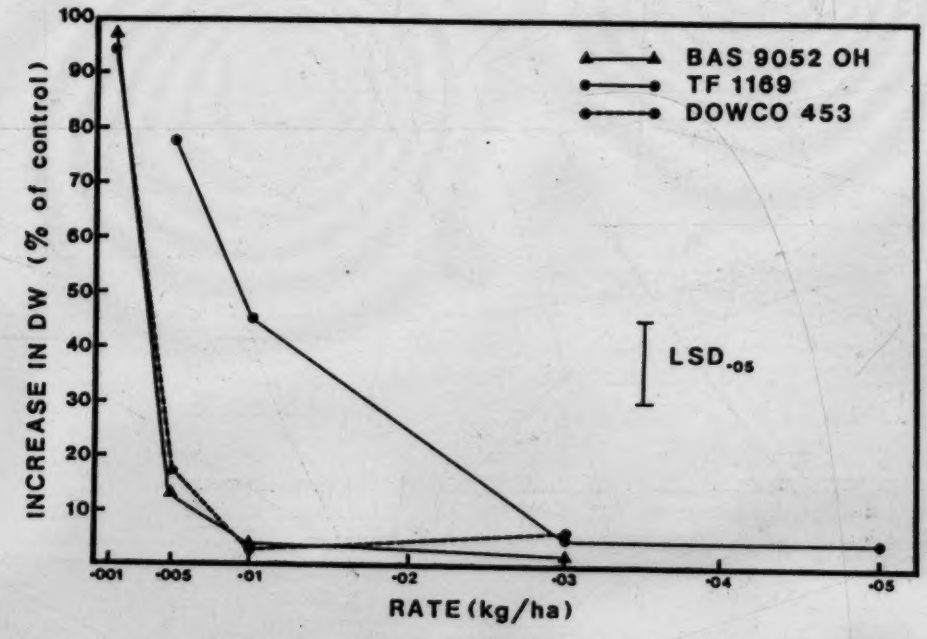


Figure 2a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of green foxtail plants, 15 days after treatment at the 2-leaf stage.

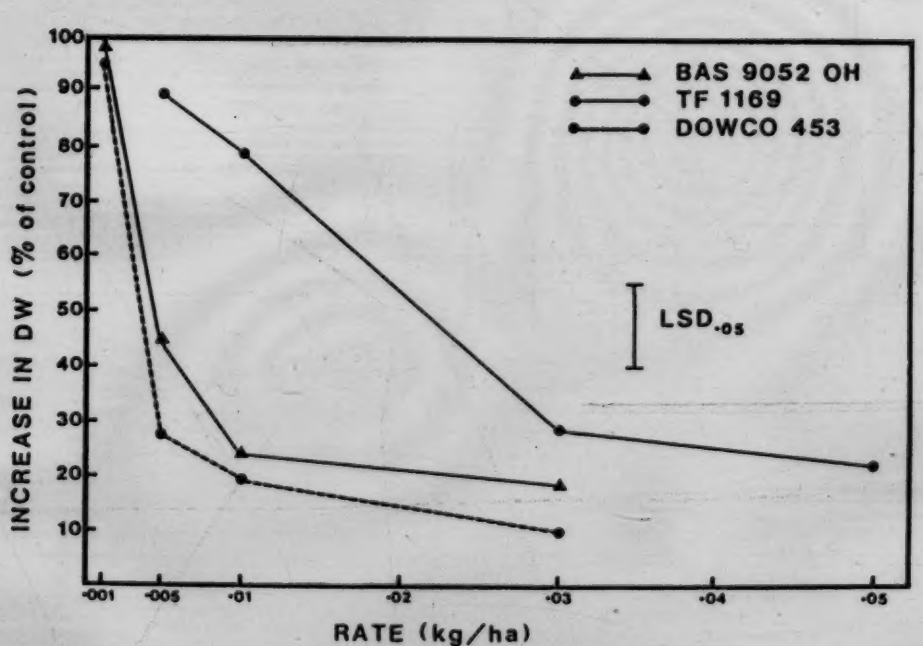


Figure 2b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of green foxtail plants, 15 days after treatment at the 4-leaf stage.

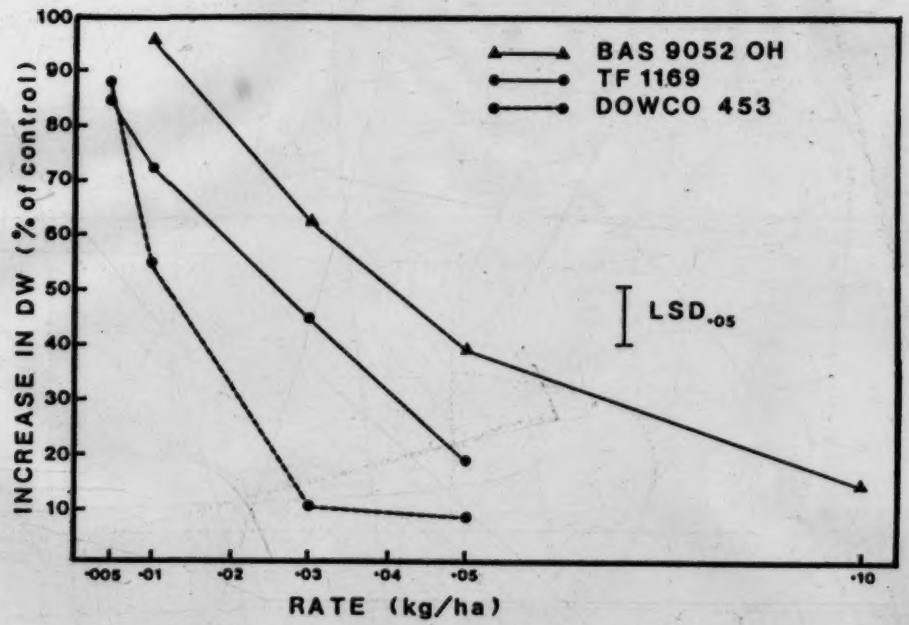


Figure 3a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of barley plants, 15 days after treatment at the 2-leaf stage.

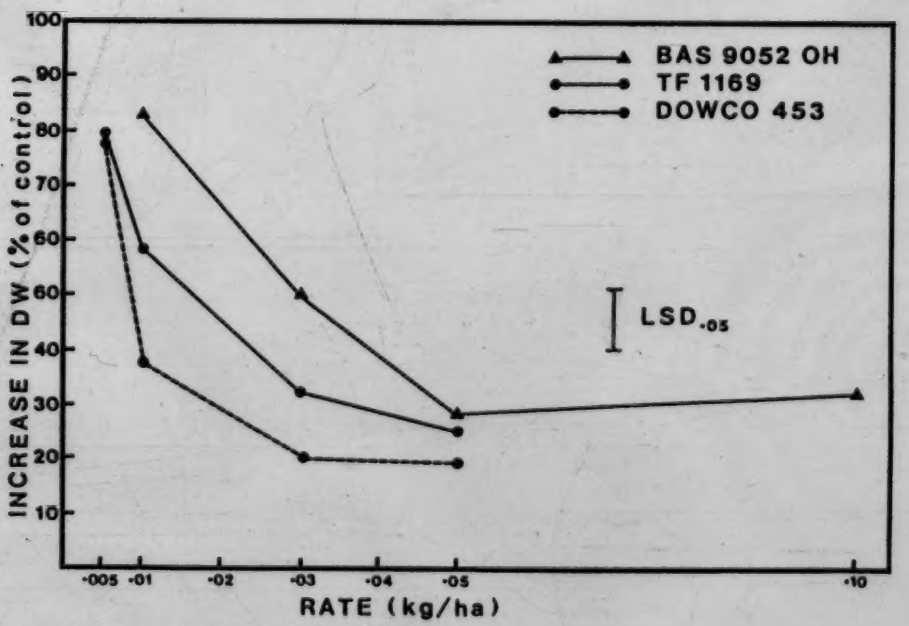


Figure 3b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the increase in dry weight of barley plants, 15 days after treatment at the 4-leaf stage.

The susceptibility of wild oats to TF 1169 or DOWCO 453 was not significantly different at the two growth stages and the plants were killed by 0.03 kg/ha or more of these herbicides.

Green foxtail was highly susceptible to BAS 9052 OH and DOWCO 453 and plants were killed by 0.005 kg/ha or more of these herbicides at both growth stages. TF 1169 was much less effective on this species, and GR_{50} values were two to three times as high as for the other two herbicides (Table 7). This difference was especially marked at the 4-leaf stage.

Table 7. **GR_{50} values of the herbicides on grass weeds.**

Weed†		GR_{50} values (g/ha)‡		
		BAS 9052 OH	TF 1169	DOWCO 453
Wild oats	2 LS	14.1 ± 3.7	16.6 ± 3.0	12.6 ± 2.8
	4 LS	22.9 ± 4.3	20.5 ± 3.4	18.0 ± 3.2
Green foxtail	2 LS	4.1 ± 1.3	12.1 ± 2.8	4.2 ± 1.2
	4 LS	6.0 ± 0.9	21.2 ± 3.2	5.0 ± 1.2
Barley	2 LS	39.6 ± 3.9	27.4 ± 2.6	13.3 ± 3.8
	4 LS	31.2 ± 3.9	23.0 ± 4.9	15.4 ± 2.0

† LS refers to leaf stage of the weeds at the time of treatment.
‡Numbers following ± represent confidence limits on GR_{50} values, calculated according to the method described by Steel and Torrie (122).

Barley was most susceptible to DOWCO 453 and least susceptible to BAS 9052 OH. The susceptiblity of plants to BAS 9052 OH was significantly higher at the 4-leaf stage than at the 2-leaf stage (Table 7). The plants did not

differ in susceptibility at the two growth stages to TF 1169 or to DOWCO 453 and were killed by 0.03 kg/ha of these herbicides or 0.05 kg/ha of BAS 9052 OH.

Injury symptoms such as inhibition of growth and development of chlorosis on the young growing tissue caused by BAS 9052 OH, TF 1169, and DOWCO 453 indicated that the primary effect of these herbicides was on the actively growing tissue. BAS 9052 OH, TF 1169, and DOWCO 453 appear to be slow-acting herbicides. Symptoms did not occur until 3 to 4 days after treatment. During this period, growth continued and the dry weight of plants increased. The increase in dry weight of plants was greater when the herbicides were applied at an advanced than at an early growth stage which indicated that application of the herbicides at the early (2- to 3-leaf) growth stage of annual grasses could prove advantageous since the weeds would offer less competition to the crops before and after herbicide application. Wild oats can exert its competitive effects on rapeseed right from the early stages (within 7 days of emergence). These competitive effects can increase with time up to 50 days after emergence when rapeseed yield could be reduced by about 70% (24).

4.4 Quackgrass Control in the Field

4.4.1 Control of quackgrass grown from planted rhizomes

All herbicide treatments, including glyphosate, significantly reduced the dry weight of quackgrass shoots determined 2 months after herbicide treatment (Table 8). Visual ratings indicated that, of the three experimental herbicides, DOWCO 453 was most effective in controlling quackgrass.

Table 8. **Control of quackgrass grown from planted rhizomes in the field.**

Treatment†	Rate kg/ha	Shoot growth			Regrowth'
		Score Aug 20	Culms /m²‡	D.W. g/m²‡	Score May 14
Weedy check		0	412 a	267 a	0
TF 1169	0.50	5	76 bc	30 b	3
TF 1169	0.70	7	48 bc	17 b	5
TF 1169	1.00	7	20 c	9 b	6
BAS 9052 OH	0.35	4	150 b	54 b	2
BAS 9052 OH	0.50	6	57 bc	18 b	4
BAS 9052 OH	0.70	7	36 c	13 b	6
DOWCO 453	0.35	8	11 c	4 b	7
DOWCO 453	0.50	9	0 c	0 b	8
DOWCO 453	0.70	9	0 c	0 b	9
Glyphosate	1.00	8	37 c	18 b	6

†All treatments were applied at the 3- to 4-leaf stage of quackgrass plants.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.
'Regrowth in the treated plots was visually rated in the year after herbicide application.

Visual observations in May 1982 showed that the herbicide treatments resulted in a thinner stand of quackgrass than the control the following year. The treatments with DOWCO 453 were most effective in preventing quackgrass regrowth (Table 8). The highest rate of TF 1169 or BAS 9052 OH was as effective as glyphosate at 1 kg/ha. Barley seeded in the herbicide-treated plots in the year after herbicide application was not affected by any of the treatments.

4.4.2 Control of established quackgrass

TF 1169 at 0.5 kg/ha or more was as effective as glyphosate at 1 kg/ha in reducing the dry weight of quackgrass in an established stand (Table 9). Visual observations indicated that BAS 9052 OH alone or in combination with TF 1169 was less effective than TF 1169 applied alone at 0.5 kg/ha or glyphosate at 1 kg/ha.

Visual observations in the spring of 1982 indicated that none of the treatments, including glyphosate, was effective in preventing quackgrass regrowth the following year.

Table 9. Control of established quackgrass.

Treatment†	Rate kg/ha	Shoot growth		Regrowth'
		Score Aug 22	Dry wt. g/m²‡	Score May 30
Weedy check		0	127 a	0
TF 1169	0.25	4	65 bc	1
TF 1169	0.50	6	45 c	5
TF 1169	1.00	7	31 c	4
BAS 9052 OH	0.25	3	99 ab	0
BAS 9052 OH	0.50	4	144 a	1
BAS 9052 OH	0.70	5	67 bc	3
TF1169+BAS9052	0.25+0.25	5	65 bc	2
TF1169+BAS9052	0.50+0.25	5	63 bc	3
Glyphosate	1.00	7	24 c	5

†Atplus 411F at 0.25% and Agral 90 at 0.05% (v/v) of the final spray volume were added to the mixture of BAS 9052 OH and TF 1169. All treatments were applied at the 3- to 4-leaf stage of quackgrass.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.
'Regrowth in the treated plots was visually rated in the year after herbicide application.

4.5 Effect of the Herbicides on Growth of Quackgrass

4.5.1 Injury symptoms

Injury symptoms on quackgrass became evident within 4 days of treatment with BAS 9052 OH or DOWCO 453 and within 5 days of treatment with TF 1169. The first symptoms were inhibition of growth and the development of chlorosis near the base of the youngest leaf. This initial chlorosis

progressively spread towards the tip of the youngest leaf and on older leaves. Some older leaves showed a purple coloration near the base. Gradually, the whole plant turned chlorotic and the stem became weak and necrotic. Death of the plant occurred within 2 to 3 weeks of treatment.

At low rates of the herbicides, curling and crinkling symptoms appeared near the base of the youngest leaf. Chlorosis did not spread on older leaves and the plants were not killed, although growth was inhibited within 1 week of treatment. Some plants recovered from this initial suppression and resumed normal growth. At high rates, injury symptoms were enhanced and death occurred within 2 weeks of treatment.

4.5.2 Dry weight of shoots and viability of rhizomes

All herbicide treatments, except the lowest rate of the herbicides, significantly inhibited the increase in quackgrass shoot dry weight when applied at the 2- to 3-leaf or 4- to 5-leaf stage in the greenhouse (Figure 4). Efficacy of the herbicides, however, was lower at the advanced growth stage than at the early growth stage. All herbicides were equally effective when applied at the early growth stage but DOWCO 453 was significantly more effective than BAS 9052 OH or TF 1169 when applied at the advanced growth stage. Inhibition of growth and severe leaf chlorosis occurred after treatment with 0.05 kg/ha of DOWCO 453 or 0.10 kg/ha of BAS 9052 OH or TF 1169.

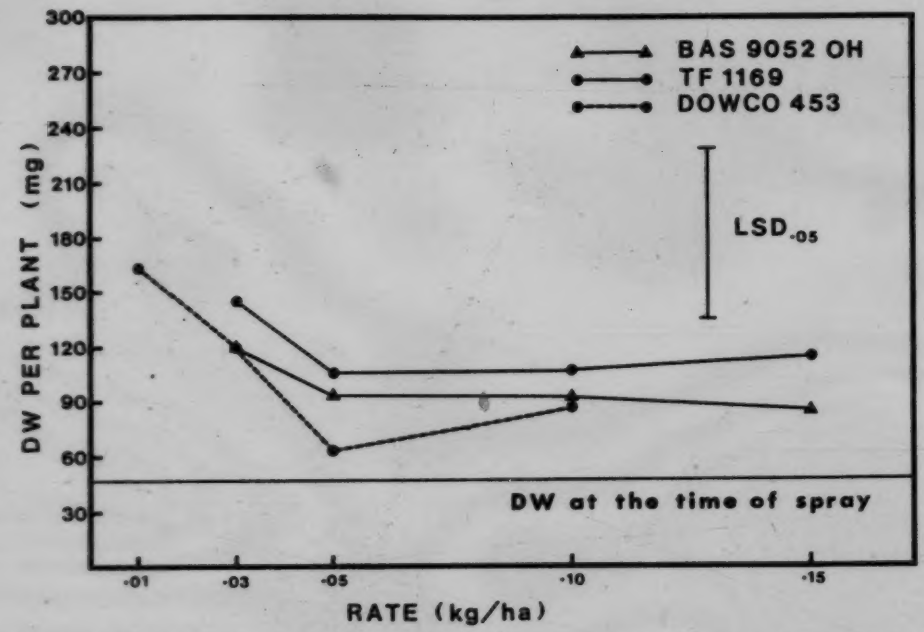


Figure 4a. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the dry weight of quackgrass plants, 15 days after treatment at the 2-leaf stage. (DW of control plants at harvest was 229 mg)

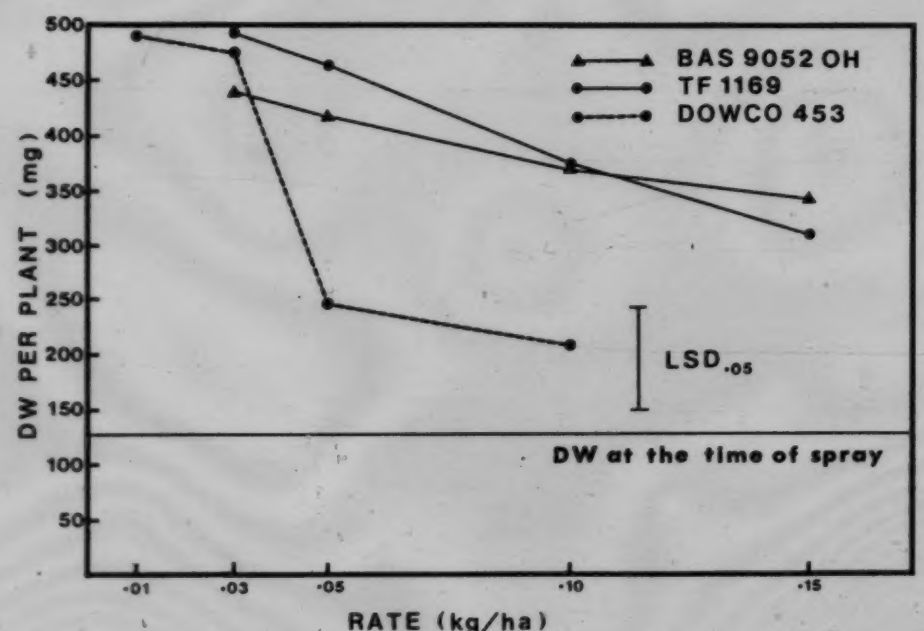


Figure 4b. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on the dry weight of quackgrass plants, 15 days after treatment at the 4-leaf stage. (DW of control plants at harvest was 476 mg)

Regrowth of quackgrass plants from rhizomes was observed after the shoots had been removed 15 days after treatment at both stages of growth. All three herbicides reduced the number and dry weight of resprouted quackgrass shoots (Table 10).

Table 10. **Regrowth of quackgrass in the greenhouse.**

Treatment	Rate kg/ha	Percentage of shoots resprouted		Dry weight mg/shoot	
		2 LS†	4 LS	2 LS	4 LS
Control		95	95	55	55
BAS 9052 OH	0.03	90	100	71	106
BAS 9052 OH	0.05	75	76	83	60
BAS 9052 OH	0.10	11	0	8	0
BAS 9052 OH	0.15	0	0	0	0
TF 1169	0.03	100	94	61	78
TF 1169	0.05	88	88	74	87
TF 1169	0.10	13	69	7	84
TF 1169	0.15	0	24	0	31
DOWCO 453	0.01	94	84	59	83
DOWCO 453	0.03	19	5	14	1
DOWCO 453	0.05	0	0	0	0
DOWCO 453	0.10	0	0	0	0
L.S.D. (0.05)		21	21	33	33

†LS refers to leaf stage of quackgrass plants at the time of treatment.

BAS 9052 OH or TF 1169 at 0.10 kg/ha reduced the number of shoots resprouted by more than 87% when the plants were treated at the 2- to 3-leaf stage. TF 1169 was considerably less effective than BAS 9052 OH in reducing regrowth when applied at the 4- to 5-leaf stage. DOWCO 453 was most effective in reducing the number and dry weight of

resprouted quackgrass shoots, at either of the leaf stages.

In general, BAS 9052 OH and TF 1169 at rates of up to 0.50 kg/ha did not provide satisfactory control of quackgrass grown from planted rhizomes in the field. BAS 9052 OH up to 0.70 kg/ha and TF 1169 up to 1 kg/ha did not provide satisfactory control of established quackgrass. Neither of the herbicides was effective in preventing regrowth of quackgrass in the next growing season. My results from field experiments are different from those of some other workers (47,104) who tested these herbicides under conditions of cultivation and in the presence of a crop. In my experiments, the herbicides were applied to quackgrass growing without competition from a crop, hence plants that survived herbicide treatments recovered and grew vigorously later in the season and may have produced new rhizomes.

My results from greenhouse experiments indicated that all three herbicides were very effective in controlling quackgrass shoot growth and reducing the viability of the rhizomes. These results suggested that the poor control of quackgrass with BAS 9052 OH and TF 1169 in the field experiments may have been due to the rates of these herbicides used in the field being too low.

BAS 9052 OH and TF 1169 were more effective on quackgrass grown from planted rhizome segments than from established rhizomes in the field. Fragmentation of rhizomes by cultivation has been reported to improve the efficacy of

BAS 9052 OH and TF 1169 on quackgrass (33,47,50,117,123). In my experiment, the rhizomes of established quackgrass were fragmented by discing twice in the spring. However, due to uneven depth of the rhizomes, all segments may not have given rise to shoots at the same time. Hence, plants that escaped herbicide treatments may have given rise to shoots after spraying.

DOWCO 453 was most effective in providing season-long control of quackgrass grown from planted rhizomes, at rates as low as 0.35 kg/ha. All treatments with this herbicide also were very effective in reducing regrowth of quackgrass one year after application. These results agree with the report that DOWCO 453 at 0.50 kg/ha provided effective control of quackgrass in the field (47). Greenhouse studies confirmed the results of the field experiments and indicated that the stage of growth of quackgrass did not affect the efficacy of DOWCO 453 for regrowth control.

4.6 Morphological and Histological Effects on Wild Oats

Wild oat plants at the 5-leaf stage, with the fourth internode 1 to 2 mm long, were sprayed with BAS 9052 OH or TF 1169 at 0.03 and 0.10 kg/ha, or with DOWCO 453 at 0.02 and 0.05 kg/ha. The plants were harvested 0, 2, 5, 9, and 14 days after treatment. Experiments were conducted separately for each herbicide.

4.6.1 Injury symptoms on the stem

The plants were dissected by carefully removing the leaves to expose the stem. A constriction on the stem was observed near the base of the fourth internode within 2 days of treatment with BAS 9052 OH and within 5 days of treatment with TF 1169 or DOWCO 453. During the 14 days following treatment, the constriction became progressively more severe and the tissue turned brown (Figures 5 to 8). In plants treated with BAS 9052 OH or TF 1169, the constriction also was observed near the base of the third internode in some instances. The growth and development of the panicle was inhibited with all herbicide treatments. Injury symptoms were enhanced at higher rates of the herbicides.

4.6.2 Anatomical structure

Transverse and longitudinal sections of wild oat stems taken from near the base of the fourth internode revealed an anatomical structure similar to that reported by other workers (19,45,80,89).

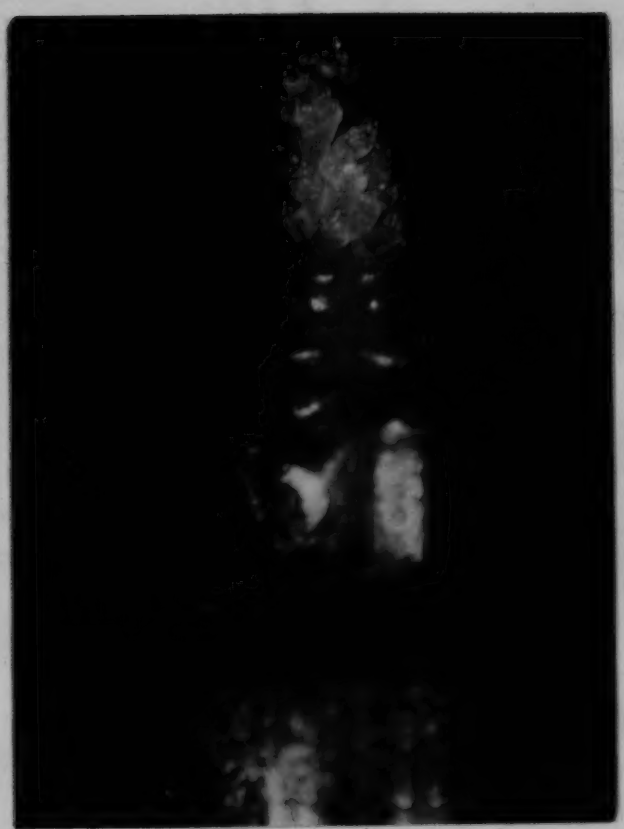


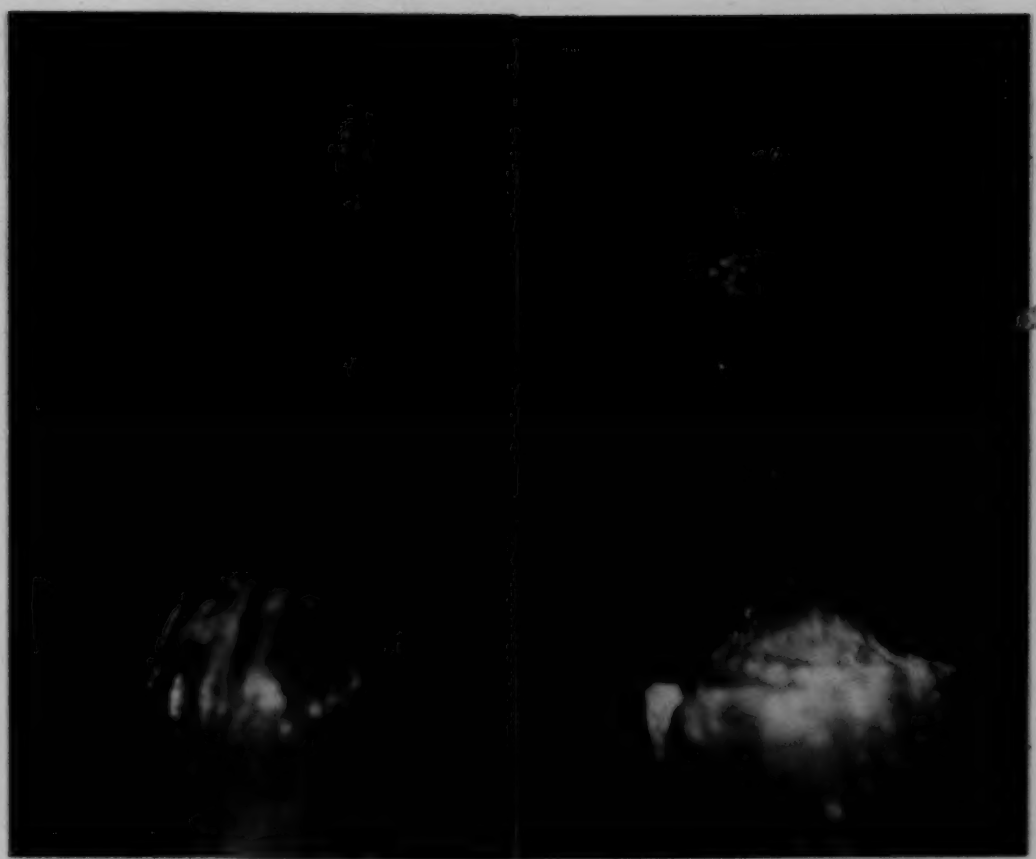
Figure 5. Part of the stem of wild oats showing the third, fourth and the upper internodes and the panicle (untreated). X30.

COLOURED PICTURES
Images en couleur

A B

Figure 6. Part of the stem of wild oats 2 days (A) and 5 days (B) after treatment with DOWCO 453 at 0.05 kg/ha. X20.

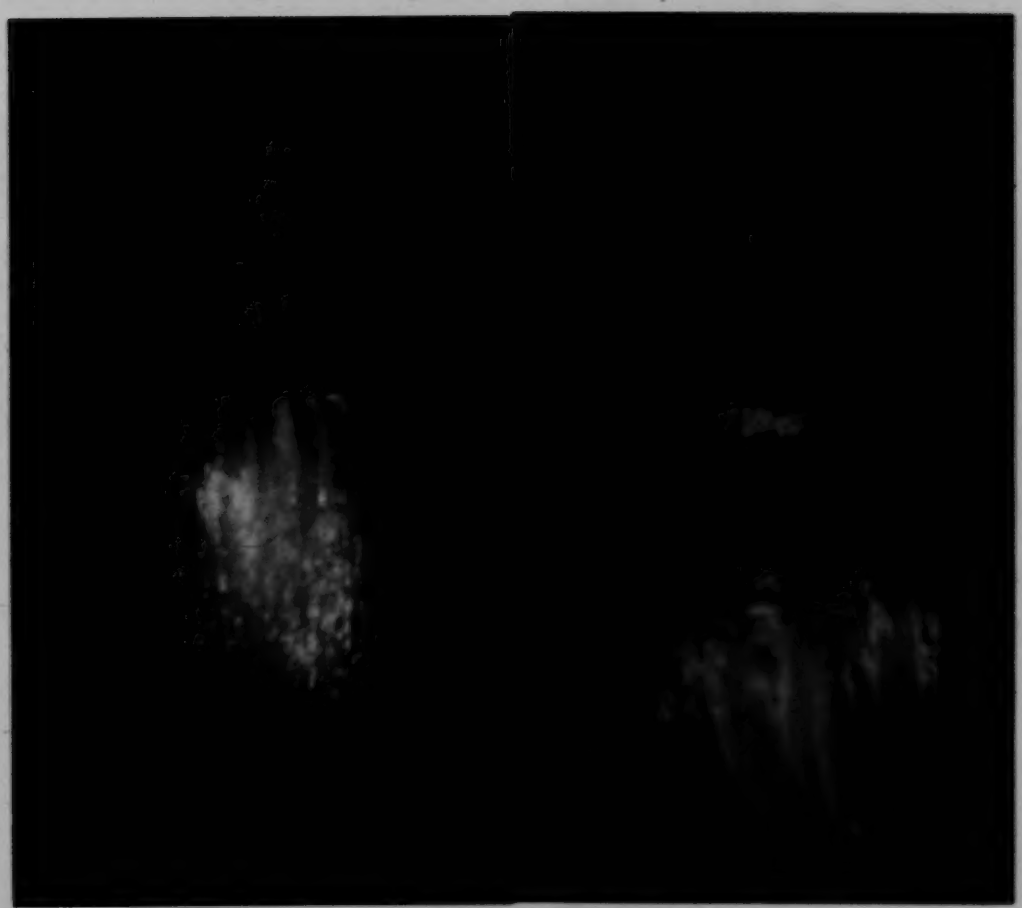
COLOURED PICTURES
Images en couleur



A B

Figure 7. Part of the stem of wild oats 9 days (A) and 14 days (B) after treatment with DOWCO 453 at 0.05 kg/ha. X20.

COLOURED PICTURES
Images en couleur



A B

Figure 8. Part of the stem of wild oats 14 days after treatment with TF 1169 at 0.1 kg/ha X20 (A) and with BAS 9052 OH at 0.1 kg/ha X30 (B).

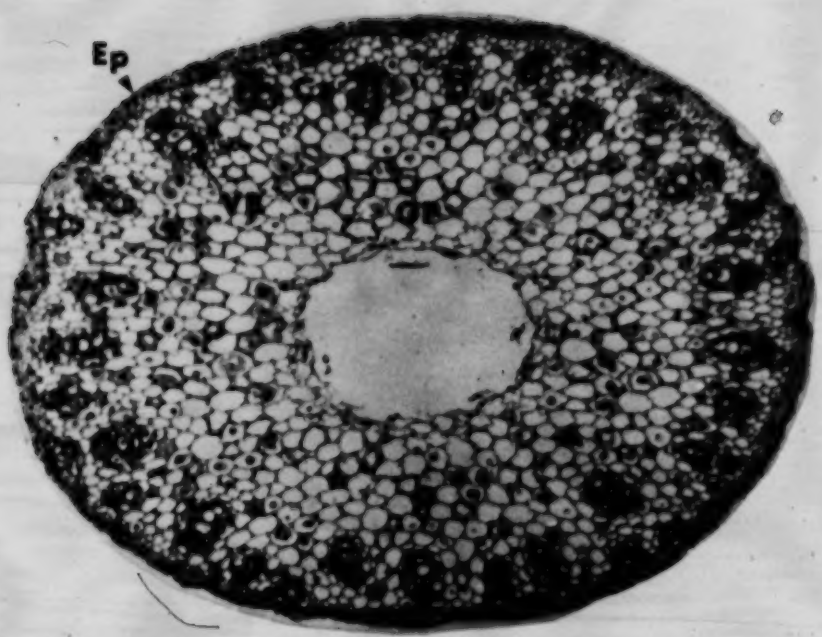
COLOURED PICTURES
Images en couleur

The epidermis was well defined and the vascular bundles were arranged in two circles (Figures 9 to 11). Vascular bundles of the outer circle were in the process of development and were partly embedded in the sclerenchymatous tissue immediately inside the epidermis. Vascular bundles of the inner circle consisted of clearly defined xylem and phloem tissue separated by an immature tissue, procambium.

The first visible injury to the anatomical structure occurred in the peripheral region of the stem near the base of the fourth internode. The epidermis was disorganized and the cells in the cortex stained darkly within 5 days of treatment (Figures 12 and 13). Cells in the cortex, especially the procambium cells and those surrounding the vascular bundles, were killed within 9 days of treatment. The smaller vascular bundles in the outer circle were completely obliterated 14 days after treatment. The larger vascular bundles in the inner circle lost their oval shape and appeared oblong as a result of necrosis of the vascular parenchyma and obliteration of some of the metaxylem vessels and the peripheral phloem cells. The cells in the ground parenchyma assumed an amoeboid shape, but developed necrosis much later than the cells in the cortex. At higher rates of the herbicides, necrosis spread to all cells in the internode within 14 days of treatment.

Figure 9. Transverse section of wild oat stem from near the base of the fourth internode showing the epidermis (Ep), vascular bundles (VB), and the parenchymatous tissue in the cortex (Cx) and ground parenchyma (GP) (untreated). X100.

Figure 10. Transverse section of wild oat stem from near the base of the fourth internode showing the epidermis (Ep), the sclerenchymatous tissue (Sc), protophloem (PP), metaphloem (MP), xylem (Xy), and the parenchymatous tissue in the cortex (Cx) and ground parenchyma (GP) (untreated). X200.



9

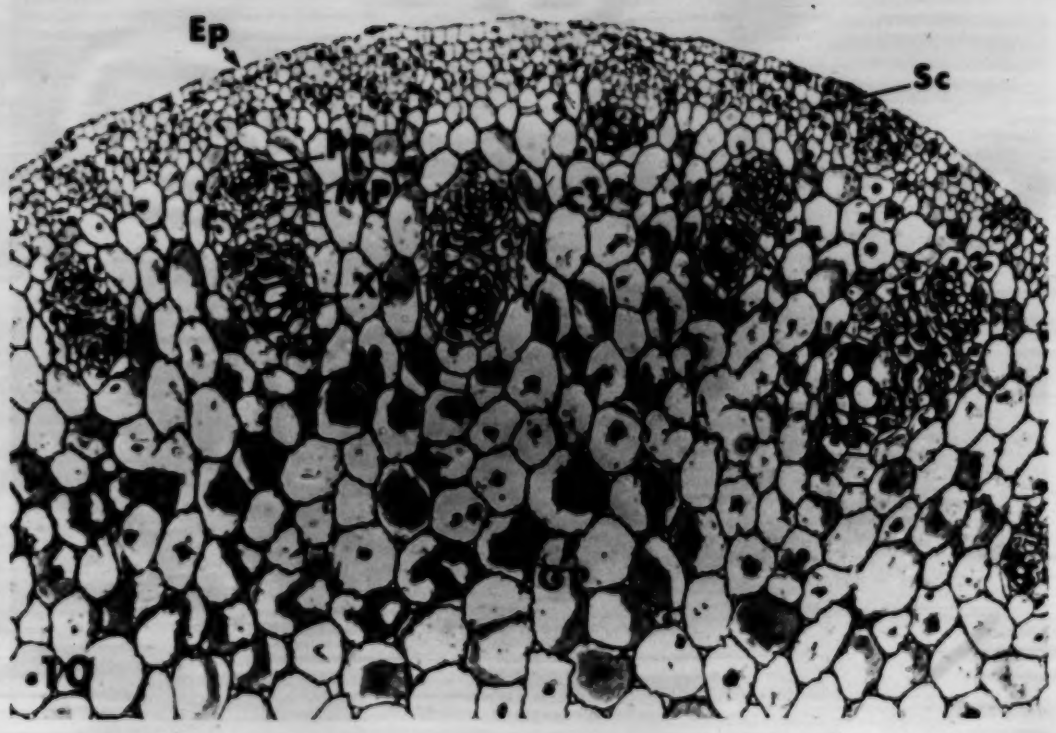


Figure 11. Longitudinal section of a part of wild oat stem showing the fourth internode (In 4), the upper internodes and the panicle (Pa). The epidermis (Ep), node (No), vascular system (VS), and the cells in the cortex (Cx) and ground parenchyma (GP) are well differentiated (untreated). X250.

11

Figure 12. Transverse sections of wild oat stem from near the base of the fourth internode of plants treated with BAS 9052 OH at 0.1 kg/ha. Ep - epidermis; Cx - cortex; VB - vascular bundles.

a. Treated wild oat stem showing necrosis of the epidermis and the cortical parenchyma cells, 2 days after treatment. X60.

b. Same as a. X120.

c. Treated wild oat stem showing necrosis of the procambium and cortical parenchyma cells, 5 days after treatment. X60.

d. Same as c. X120.

e. Treated wild oat stem showing necrosis in the cortex region and irregular shape of cells in the ground parenchyma, 9 days after treatment. X60.

f. Same as e. X120.

g. Treated wild oat stem showing severe necrosis of the stem tissue and oblong shape of vascular bundles, 14 days after treatment. X60.

h. Same as g. X120.

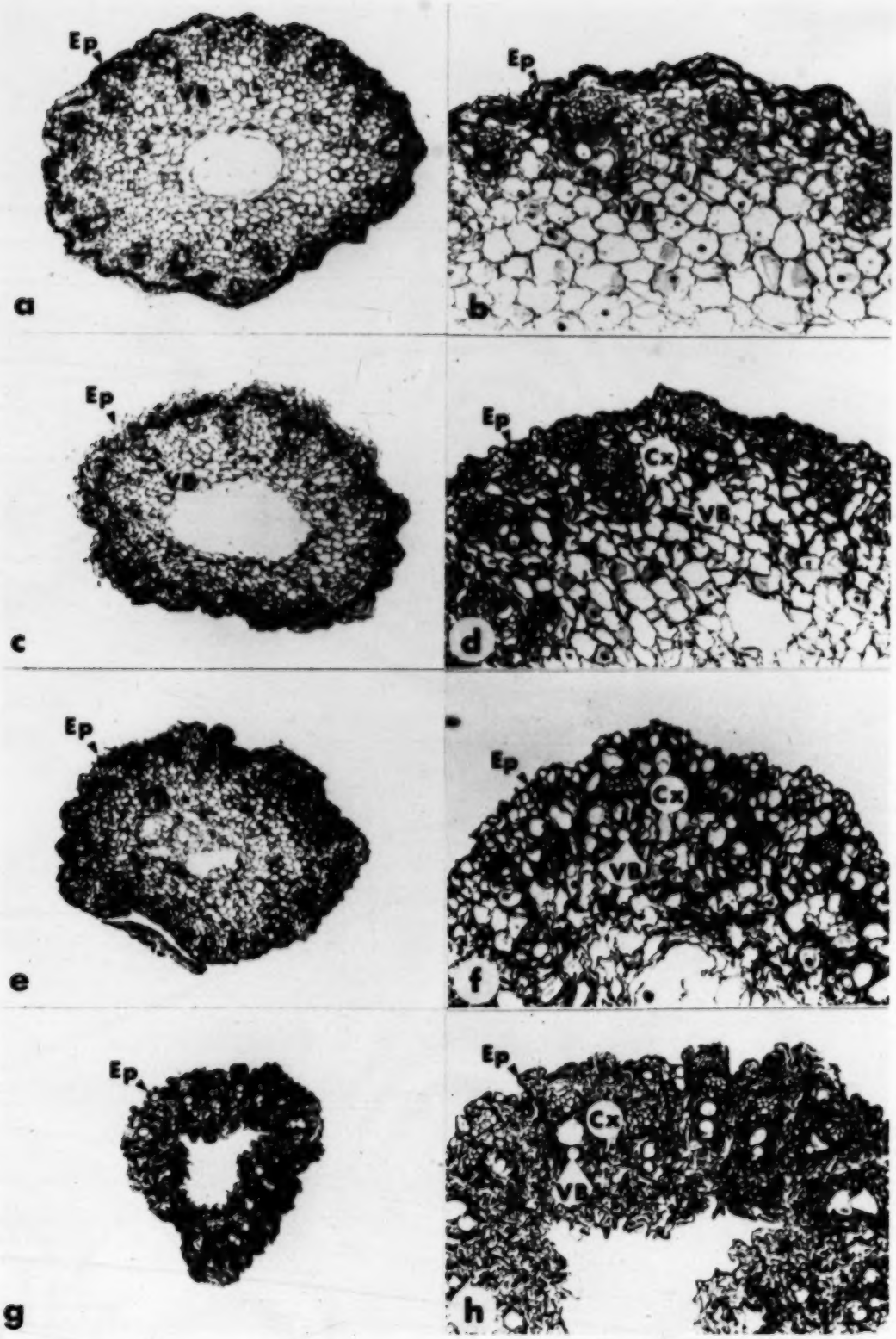

Ep
VB
a
Ep
VB
b
Ep
VB
c
Ep
Cx
VB
d
Ep
e
Ep
Cx
VB
f
Ep
g
Ep
Cx
VB
h

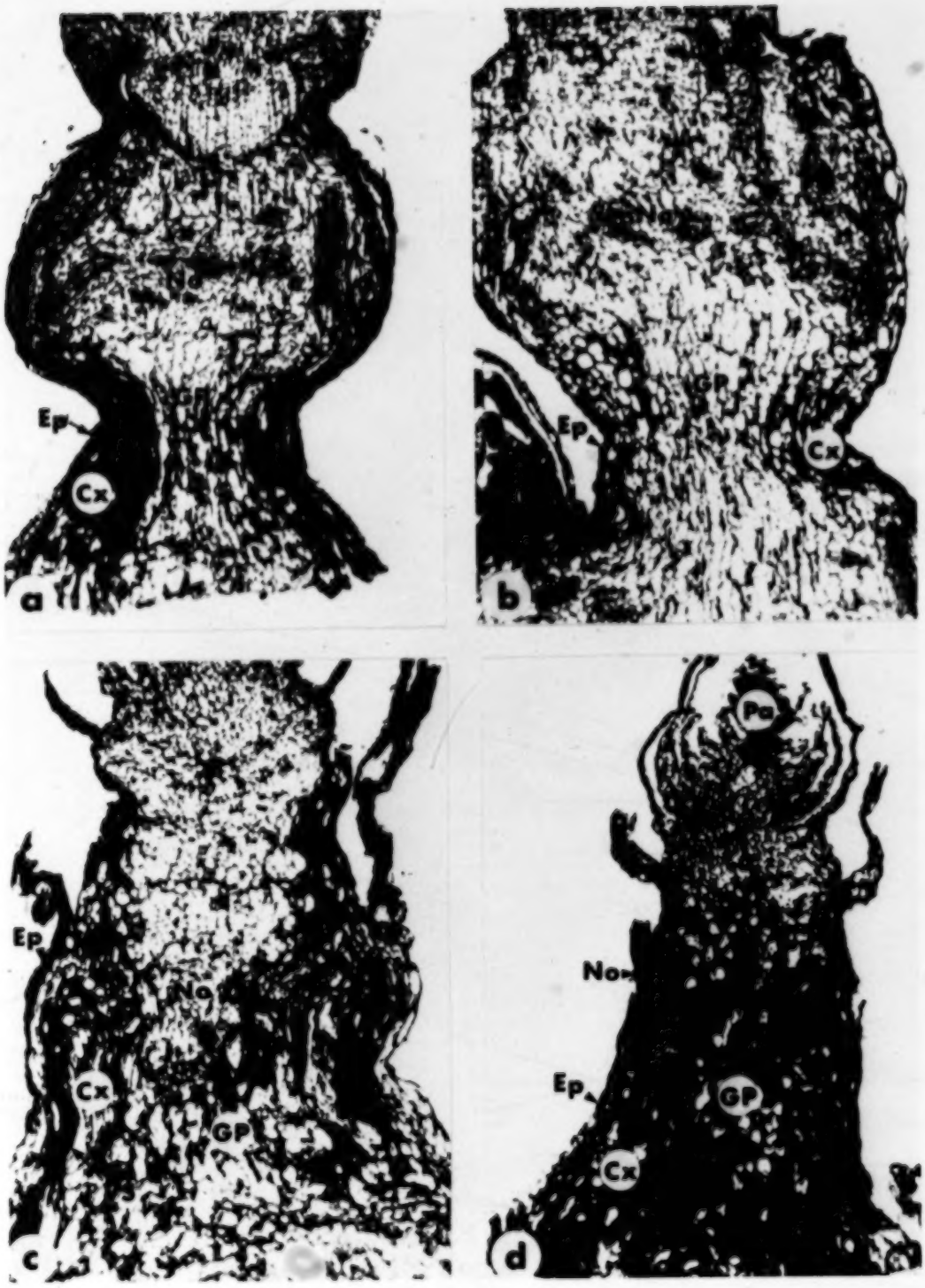
Figure 13. Longitudinal sections of the fourth internode of wild oat plants treated with BAS 9052 OH at 0.1 kg/ha. X160. Ep - epidermis; No - node; Cx - cortex; GP - ground parenchyma; VS - vascular system; Pa - panicle.

a. Treated wild oat stem showing the constriction near the base of the fourth internode and necrosis of the epidermis and cells in the cortex, 2 days after treatment.

b. Treated wild oat stem showing herbicide injury symptoms near the base of the fourth internode, 5 days after treatment.

c. Treated wild oat stem showing necrosis of the parenchymatous tissue on the outer and inner sides of the vascular system, 9 days after treatment.

d. Treated wild oat stem showing necrosis of all cells in the fourth internode and the panicle, 14 days after treatment.


Ep
Cx
a
Ep
GP
Cx
b
Ep
No
Cx
GP
c
Po
No
Ep
GP
Cx
d

4.6.3 Stem length

Elongation of the stem was inhibited significantly within 2 days of treatment with BAS 9052 OH and within 5 days of treatment with TF 1169 or DOWCO 453 (Figures 14 to 16). After this initial inhibition, the treated plants showed negligible stem elongation during the 14 days after treatment. Inhibition of stem elongation occurred as a result of inhibition of elongation of the third and the fourth internode in plants treated with BAS 9052 OH or TF 1169 and the fourth internode in plants treated with DOWCO 453. The second internode did not show significant elongation during the period of observation.

The pattern of development of the stem of wild oats was similar to that reported for cultivated oats (19,80) or wheat (97) in that internode elongation usually occurred in acropetal succession. In plants treated with BAS 9052 OH or TF 1169, both the third and the fourth internodes were in the process of elongation at the time of herbicide application. In plants treated with DOWCO 453, the third internode had nearly completed its elongation and the fourth internode was elongating most rapidly at the time of treatment. Thus, it appears that BAS 9052 OH, TF 1169, and DOWCO 453 inhibited stem elongation in wild oats by affecting the elongation of actively growing internodes.

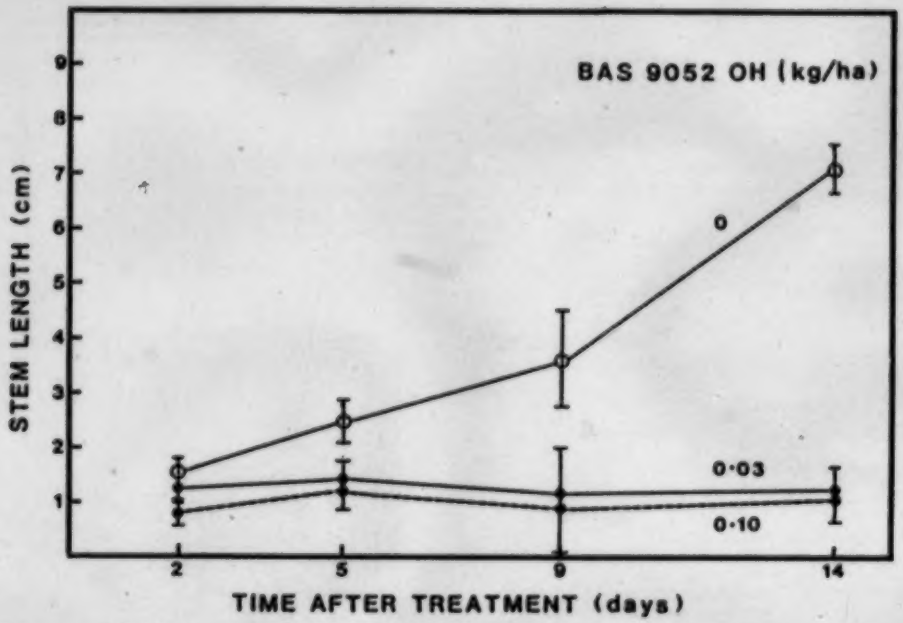


Figure 14a. Effect of BAS 9052 OH on wild oat stem elongation during 14 days after treatment.

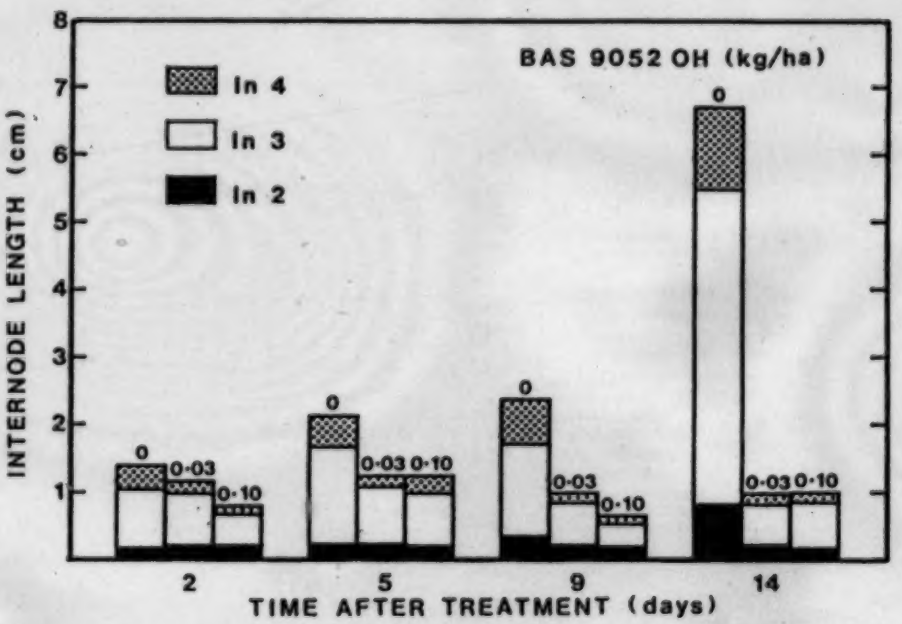


Figure 14b. Effect of BAS 9052 OH on the elongation of the second, third, and fourth internodes during 14 days after treatment.
(LSD values are given in Appendix Table III)

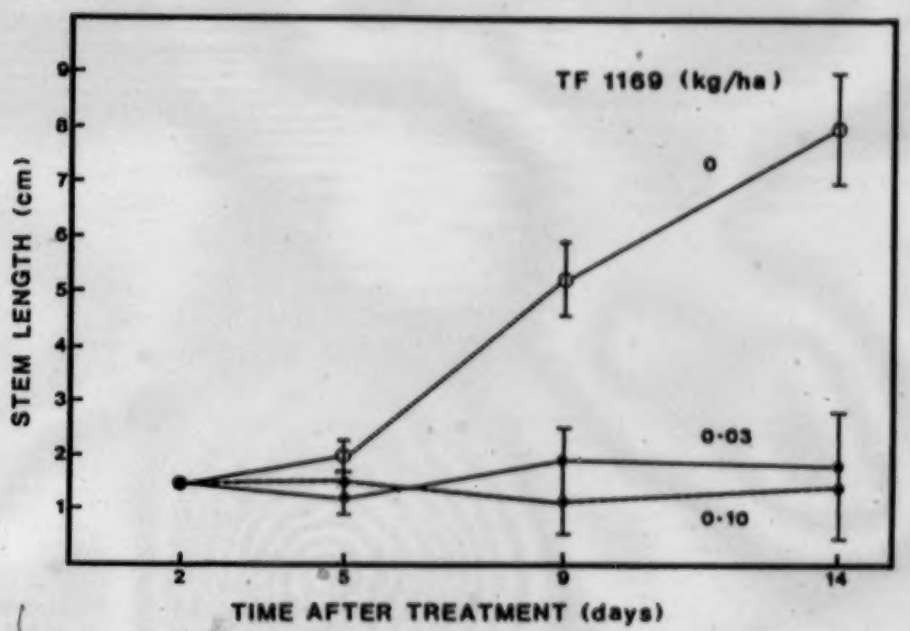


Figure 15a. Effect of TF 1169 on wild oat stem elongation during 14 days after treatment.

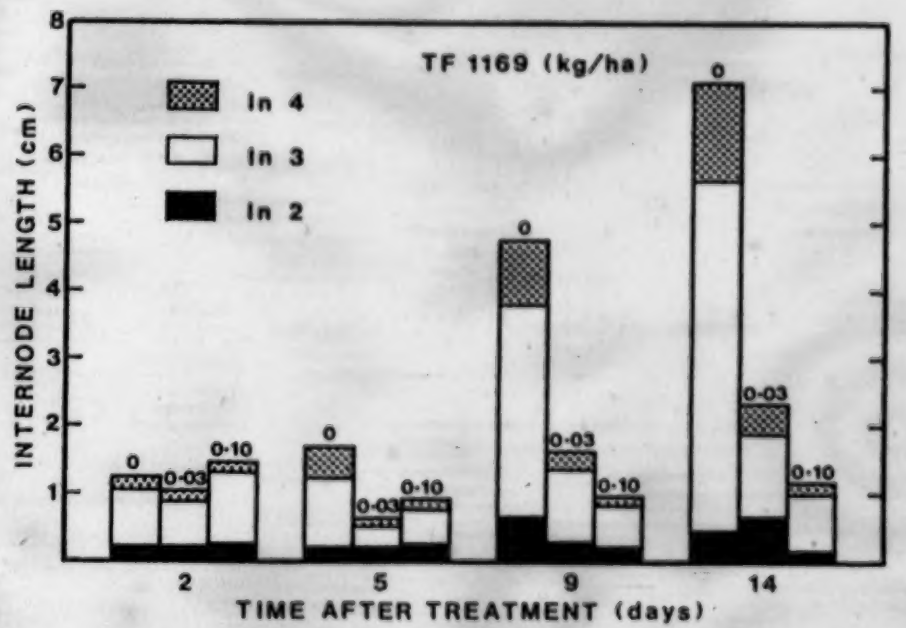


Figure 15b. Effect of TF 1169 on the elongation of the second, third, and fourth internodes during 14 days after treatment.
(LSD values are given in Appendix Table III)

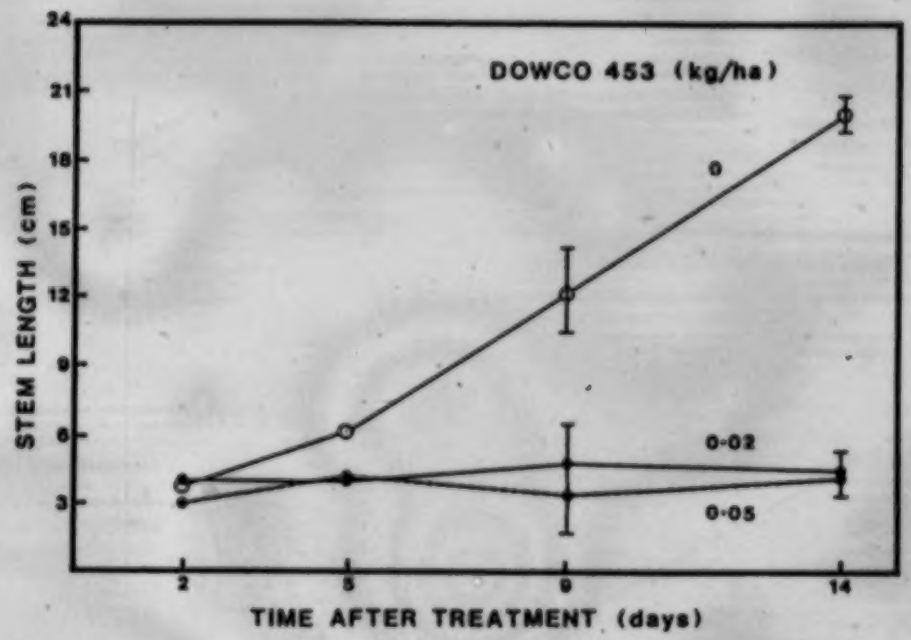


Figure 16a. Effect of DOWCO 453 on wild oat stem elongation during 14 days after treatment.

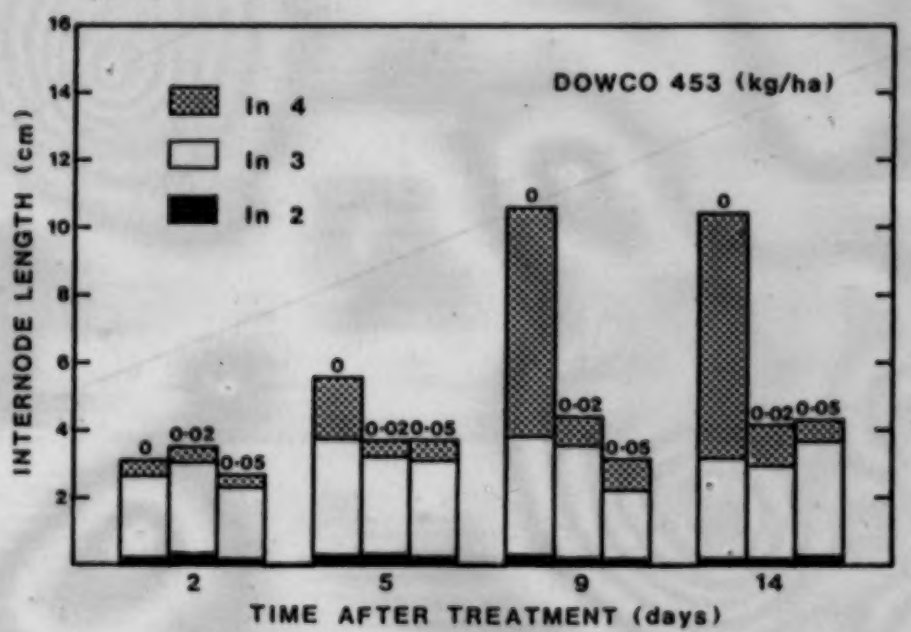


Figure 16b. Effect of DOWCO 453 on the elongation of the second, third, and fourth internodes during 14 days after treatment.
(LSD values are given in Appendix Table III)

4.6.4. Culm diameter

The increase in culm diameter near the base of the fourth internode was significantly reduced by all herbicide treatments, except the lower rate of BAS 9052 OH, 5 days after treatment. Consequently, culm diameter of plants treated with BAS 9052 OH or DOWCO 453 and plants treated with TF 1169 was about 50% and 65%, respectively, of that of control plants 14 days after treatment (Table 11).

Table 11. **Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on culm diameter.**

Treatment†	Rate kg/ha	Culm diameter (mm)‡ Days after treatment 2	5	9	14
Control		1.2 a	1.4 a	1.6 a	1.6 a
BAS 9052 OH	0.03	1.2 a	1.2 ab	1.0 b	1.2 b
BAS 9052 OH	0.10	1.0 a	1.0 b	1.1 b	0.8 b
Control		1.5 a	1.5 a	1.5 a	1.7 a
TF 1169	0.03	1.2 a	1.2 b	1.1 b	1.3 b
TF 1169	0.10	1.2 a	1.1 b	1.0 b	1.1 b
Control		1.2 a	1.5 a	1.6 a	1.9 a
DOWCO 453	0.02	1.4 a	1.1 b	1.0 b	1.0 b
DOWCO 453	0.05	1.3 a	0.9 b	0.9 b	0.9 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. values at $P \leq 0.05$.

The reduction in culm diameter occurred as a result of inhibition of lateral expansion of the culm. In addition to inhibition of lateral expansion, some herbicide treatments, especially those with DOWCO 453, caused an actual reduction in culm diameter near the base of the fourth internode,

possibly due to desiccation of the tissue.

4.6.5 Vascular bundle diameter

All herbicide treatments, except the lower rate of BAS 9052 OH, inhibited the increase in diameter of vascular bundles of the inner circle within 5 days of treatment. Consequently, the diameter of vascular bundles of plants treated with BAS 9052 OH, TF 1169 or DOWCO 453 was 77%, 86% and 57%, respectively, of that of control plants 9 days after treatment (Table 12).

Table 12. **Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on vascular bundle diameter.**

Treatment†	Rate kg/ha	Vascular bundle diameter (μm)‡ Days after treatment 2	5	9	14
Control		97 a	122 a	118 a	-
BAS 9052 OH	0.03	97 a	112 ab	94 b	-
BAS 9052 OH	0.10	99 a	85 b	91 b	-
Control		124 a	113 a	105 a	107 a
TF 1169	0.03	90 a	92 b	95 b	96 b
TF 1169	0.10	96 a	97 b	82 b	92 b
Control		98 a	113 a	129 a	151 a
DOWCO 453	0.02	100 a	91 b	84 b	90 b
DOWCO 453	0.05	95 a	87 b	87 b	87 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. values at $P \leq 0.05$.
Observations were not recorded 14 days after treatment with BAS 9052 OH, due to severe necrosis of the tissue.

Although the size of various component cells of the vascular bundles was not determined, it appeared that the

increase in vascular bundle diameter was reduced as a result of inhibition of lateral expansion of the vascular parenchyma cells. The procambium and the vascular parenchyma cells were very sensitive to the herbicide treatments and showed necrosis within 9 days of treatment. The differentiation of new xylem and phloem elements was prevented. The metaxylem vessels and the metaphloem cells that had differentiated before the plants were treated were also obliterated as a result of which the bundles lost their oval shape and became oblong within 14 days of treatment. This probably was the reason for an actual reduction in bundle diameter after DOWCO 453 treatments.

4.6.6 Diameter of cells in the cortex

The diameter of cells in the cortex between the vascular bundles in the inner circle was measured on transverse sections of the stem. All herbicide treatments except the low rate of BAS 9052 OH inhibited the increase in cell diameter within 5 days of treatment. In plants treated with BAS 9052 OH, TF 1169, or DOWCO 453, cell diameter was about 75%, 67% and 54%, respectively, of that of control plants 9 days after treatment (Table 13).

In addition to inhibiting lateral expansion of cells in the cortex, treatments with DOWCO 453 caused a real reduction in cell diameter, possibly due to desiccation of the tissue and severe necrosis of the cells within 14 days of treatment.

Table 13. **Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on diameter of cells in the cortex.**

Treatment†	Rate kg/ha	Cell diameter (μm)‡ Days after treatment 2	5	9
Control		25.5 a	31.0 a	33.8 a
BAS 9052 OH	0.03	29.7 a	27.8 ab	24.7 b
BAS 9052 OH	0.10	23.0 a	21.0 b	25.3 b
Control		28.7 a	35.7 a	37.2 a
TF 1169	0.03	25.4 a	23.8 b	27.5 b
TF 1169	0.10	25.6 a	22.9 b	25.1 b
Control		30.6 a	36.9 a	40.3 a
DOWCO 453	0.02	32.4 a	21.9 b	18.2 b
DOWCO 453	0.05	29.9 a	16.0 b	18.5 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. value at $P \leq 0.05$.

4.6.7 Width of cells in the ground parenchyma

The width of cells in the ground parenchyma was measured on longitudinal sections taken from near the base of the fourth internode. In plants treated with TF 1169 or DOWCO 453, increase in the width of cells in the ground parenchyma was inhibited within 5 days of treatment (Table 14). Consequently, cell width in plants treated with these herbicides was only 60% and 52%, respectively, of that of control plants 9 days after treatment. In plants treated with BAS 9052 OH, cell width was significantly less than in control plants 2 days after treatment, but not 5 or 9 days after treatment. This was due to high variability in the

data (Table 14).

Table 14. Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on width of cells in ground parenchyma.

Treatment†	Rate kg/ha	Cell width (µm)‡ Days after treatment 2	5	9
Control		44.7 a	33.3 a	40.8 a
BAS 9052 OH	0.03	37.8 ab	33.7 a	32.8 a
BAS 9052 OH	0.10	26.1 b	29.6 a	32.5 a
Control		44.2 a	39.0 a	48.7 a
TF 1169	0.03	39.7 a	30.8 b	32.5 b
TF 1169	0.10	35.7 a	30.2 b	29.1 b
Control		33.7 a	42.9 a	57.4 a
DOWCO 453	0.02	32.2 a	30.1 b	33.7 b
DOWCO 453	0.05	33.7 a	30.8 b	29.6 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. values at $P \leq 0.05$.

In general, inhibition of lateral expansion of the vascular bundles and the cells in the cortex and ground parenchyma must have contributed to the reduction in lateral expansion of the culm near the base of the fourth internode. The high susceptibility of the cells in the epidermis and the cortex, including the procambium in the vascular bundles, revealed that inhibition of cell division also may have contributed to inhibition of lateral expansion of the culm since the diameter of oat internodes increased first by periclinal cell divisions in the internode periphery, in narrow zones just beneath the epidermis, and finally by cell enlargement (19).

4.6.8 Length of cells in the cortex

Cell elongation in the cortex near the base of the fourth internode was inhibited within 9 days of treatment with DOWCO 453 (Table 15). The differences in cell lengths between plants treated with BAS 9052 OH or TF 1169 and the controls were not very apparent during the period of observation.

Table 15. **Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on cell elongation in the cortex.**

Treatment†	Rate kg/ha	Cell length (µm)‡ Days after treatment 2	5	9
Control		42.8 a	31.3 a	41.1 a
BAS 9052 OH	0.03	30.4 ab	31.4 a	30.0 a
BAS 9052 OH	0.10	22.9 b	32.8 a	31.7 a
Control		33.3 a	32.7 a	41.3 a
TF 1169	0.03	35.1 a	29.7 a	32.2 b
TF 1169	0.10	32.5 a	27.4 a	35.6 ab
Control		32.6 a	37.0 a	73.5 a
DOWCO 453	0.02	33.8 a	36.8 a	36.3 b
DOWCO 453	0.05	29.6 a	38.4 a	37.7 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. values at $P \leq 0.05$.

The lengths of cells in the cortex of control plants in experiments with BAS 9052 OH and TF 1169 did not increase appreciably during the 9 days after treatment. Lengths of cells in plants treated with DOWCO 453 increased considerably between 5 and 9 days after treatment. This probably was the reason that inhibition of cell elongation

by DOWCO 453 was much more apparent than by BAS 9052 OH or TF 1169 during the period of observation.

4.6.9 Length of cells in the ground parenchyma

The lengths of cells measured in the ground parenchyma were significantly less in plants treated with DOWCO 453 than in control plants 9 days after treatment (Table 16). Lengths of cells in plants treated with TF 1169 were significantly less than in control plants 5 days after treatment but not 9 days after treatment due to high variability in the data.

Table 16. **Effect of BAS 9052 OH, TF 1169, and DOWCO 453 on cell elongation in the ground parenchyma.**

Treatment†	Rate kg/ha	Cell length (μm)‡ Days after treatment 2	5	9
Control		40.3 a	28.6 a	43.9 a
BAS 9052 OH	0.03	26.7 a	30.4 a	29.2 b
BAS 9052 OH	0.10	25.0 a	30.8 a	33.1 ab
Control		34.9 a	35.8 a	41.2 a
TF 1169	0.03	31.5 a	28.2 b	34.7 a
TF 1169	0.10	37.4 a	26.6 b	35.3 a
Control		33.4 a	39.6 a	77.1 a
DOWCO 453	0.02	34.8 a	37.8 a	38.3 b
DOWCO 453	0.05	31.5 a	37.5 a	37.7 b

†Experiments with each herbicide were conducted separately.
‡Numbers in the same column for each herbicide followed by the same letter do not differ significantly according to L.S.D. values at $P \leq 0.05$.

As in the cortex, cell lengths in the ground parenchyma of control plants did not increase appreciably in

experiments with BAS 9052 OH and TF 1169 during 9 days after treatment. In the experiment with DOWCO 453, cell lengths increased rapidly between 5 and 9 days after treatment. Consequently, cell lengths in plants treated with BAS 9052 OH and TF 1169 were about 75% and 85%, respectively, while cell lengths in plants treated with DOWCO 453 were only about 50% of that of control plants, 9 days after treatment.

The differences in cell elongation in experiments with BAS 9052 OH, TF 1169 and DOWCO 453, possibly were due to differences in the stage of development of plants at the time of herbicide application. At the time of BAS 9052 OH or TF 1169 application, the fourth internode had just begun to elongate. At the time of DOWCO 453 application, the fourth internode was elongating most rapidly.

Elongation of the internode occurs both by means of cell division and cell elongation which are overlapping processes during the early stages of internodal development (80). The fourth internode of control plants in experiments with BAS 9052 OH and TF 1169 increased by about 250% between 2 and 9 days after treatment. The increase in length of cells in the cortex and ground parenchyma during the same period was only about 20%. The increase in length of the fourth internode of control plants in the experiment with DOWCO 453 was about 380% and the increase in length of cells in the cortex and ground parenchyma was about 227%, 9 days after treatment. The much greater increase in length of the fourth internode than in the length of cells in this

internode, in experiments with BAS 9052 OH and TF 1169, indicated that internode elongation in these experiments must have occurred primarily as a result of cell division. In the experiment with DOWCO 453, internode elongation was occurring both as a result of cell division and cell elongation. Also, inhibition of internode elongation occurred within 2 days of treatment with BAS 9052 OH and within 5 days of treatment with TF 1169 or DOWCO 453, whereas inhibition of cell elongation was not apparent until 9 days after treatment with any of the herbicides. These observations strongly indicate that BAS 9052 OH, TF 1169, and DOWCO 453 inhibit internode elongation in wild oats by inhibiting both cell division and cell enlargement. Some other wild oat herbicides such as benzoylprop ethyl and flamprop methyl (75,76,92) and diclofop methyl (93) have shown similar activities on the stem and adventitious roots of wild oats, respectively.

4.7 Translocation Behaviour of the Herbicides in Grasses

4.7.1 Effects of site of application on wild oats

Wild oat plants at the 3-leaf stage were treated with three concentrations of BAS 9052 OH, TF 1169 or DOWCO 453. Specific volumes of the herbicide solutions (5 or 8 µl) were applied as single droplets at the tip, middle or base of the second leaf blade and also between the sheath of the second leaf and the stem. Experiments were conducted separately for each herbicide.

The dry weight of plants treated with BAS 9052 OH was significantly less than that of control plants, 15 days after treatment. Placement of the herbicide between the leaf sheath and the stem was most effective while placement at the leaf tip was least effective in inhibiting growth of plants at all concentrations of the herbicide. Placement at the base or middle of the leaf blade was intermediate in effect at the lowest concentration, but was as effective as placement between the leaf sheath and the stem at the higher concentrations (Figure 17).

The dry weight of plants treated with TF 1169 was not significantly different from that of control plants when the herbicide was applied at the tip or middle of the leaf blade, except at the highest concentration, 15 days after treatment. Placement of the herbicide between the leaf sheath and the stem resulted in significantly lower dry weight of plants at all concentrations of the herbicide.

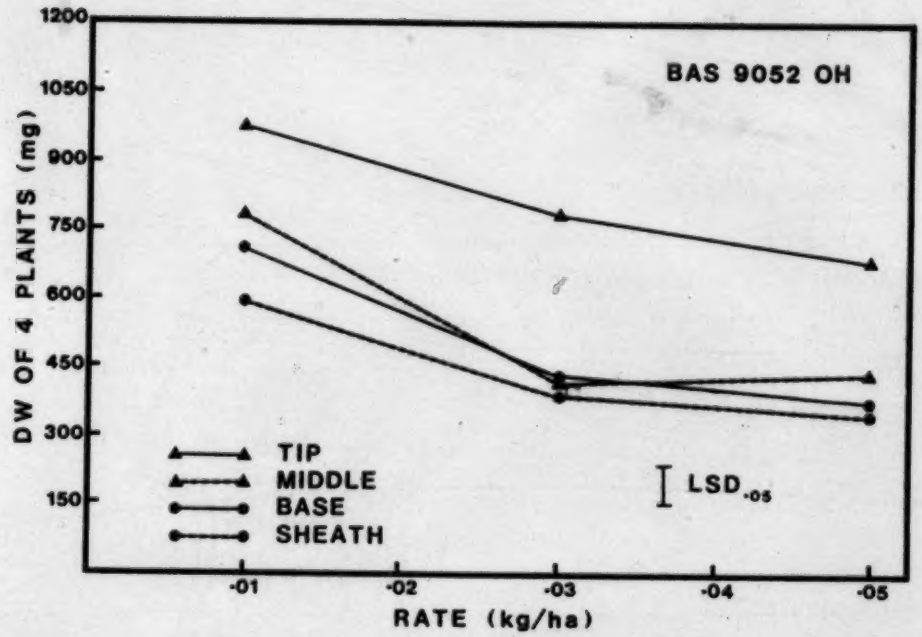


Figure 17. Effect of site of application of BAS 9052 OH on the dry weight of wild oat plants, 15 days after treatment.
(DW of control plants at harvest was 1162 mg)

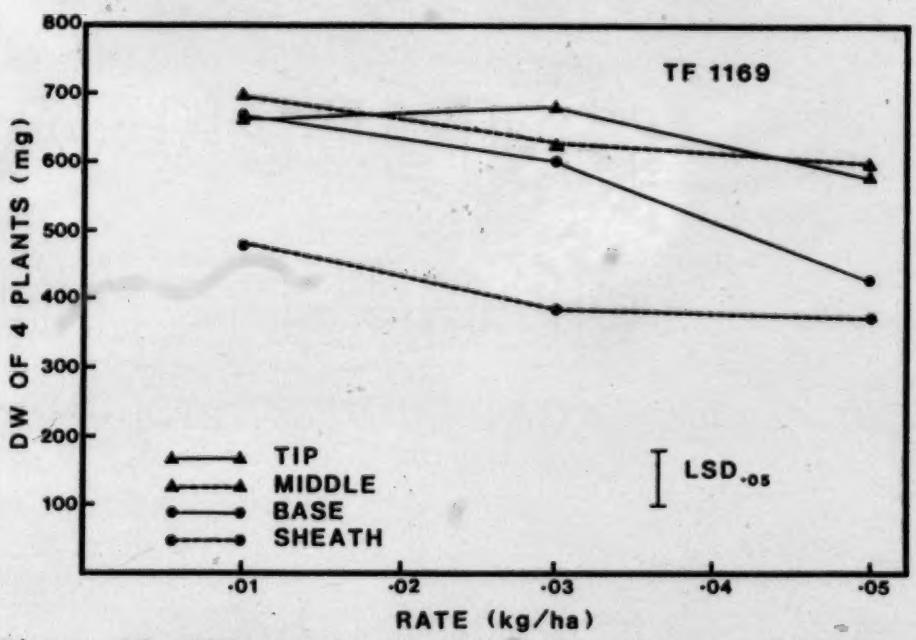


Figure 18. Effect of site of application of TF 1169 on the dry weight of wild oat plants, 15 days after treatment.
(DW of control plants at harvest was 708 mg)

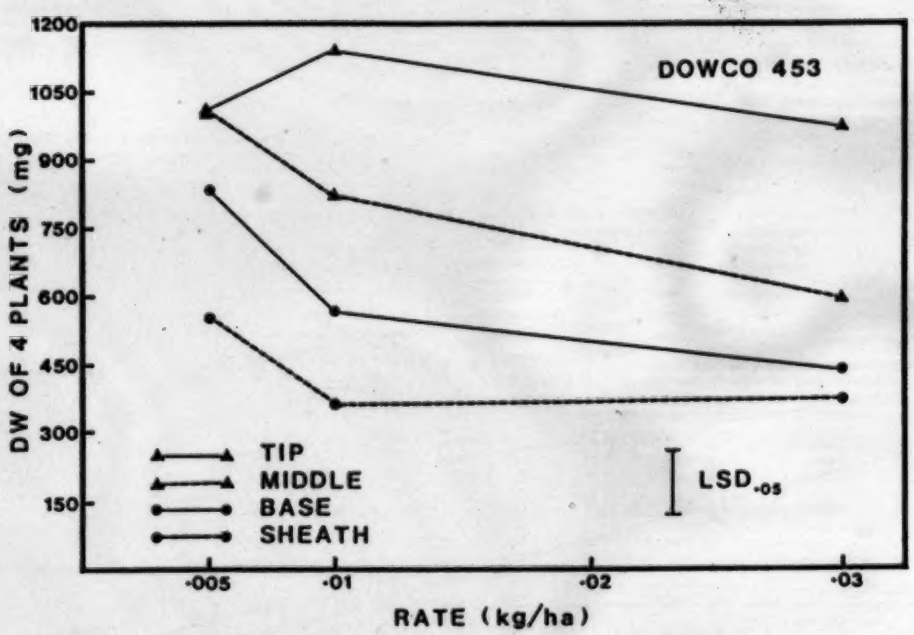


Figure 19. Effect of site of application of DOWCO 453 on the dry weight of wild oat plants, 15 days after treatment.
(DW of control plants at harvest was 1181 mg)

Placement at the base of the leaf blade was much less effective at the two lower concentrations, but was as effective as placement between the leaf sheath and the stem at the highest concentration (Figure 18).

All treatments with DOWCO 453, except the concentration corresponding to 0.01 kg/ha applied at the tip, resulted in a significantly lower dry weight of wild oat plants than the control, 15 days after treatment. Placement of the herbicide between the leaf sheath and the stem was most effective while placement at the leaf tip was least effective in inhibiting growth of plants. Placement of the herbicide at the middle or base of the leaf blade was intermediate in effect. Increasing the concentration of the herbicide

reduced the differences in effects of site of application of the herbicide at the middle or base or between the leaf sheath and the stem (Figure 19).

4.7.2 Effects of site of application on green foxtail

Green foxtail plants, at the 4-leaf stage, were treated at the tip, middle or base of the third leaf blade. A 2-µl droplet of the herbicide solution was applied at the treatment sites. Three concentrations of BAS 9052 OH, TF 1169, and DOWCO 453 were used in these studies. Experiments were conducted separately for each herbicide.

All treatments with BAS 9052 OH resulted in significantly lower dry weight of green foxtail plants, 15 days after treatment. Placement of the herbicide at the middle or base of the leaf blade was significantly more effective than placement at the tip of the leaf blade at the two lower concentrations. At the highest concentration, all treatments were equally effective in reducing the dry weight of green foxtail plants (Figure 20).

All treatments with TF 1169, except the lowest concentration, resulted in significantly lower dry weight of green foxtail plants than the control, 15 days after treatment. Placement of the herbicide at the base of the leaf blade was most effective while placement at the tip of the leaf blade was least effective at all concentrations. Treatments at the middle of the leaf blade were intermediate in effect (Figure 21).

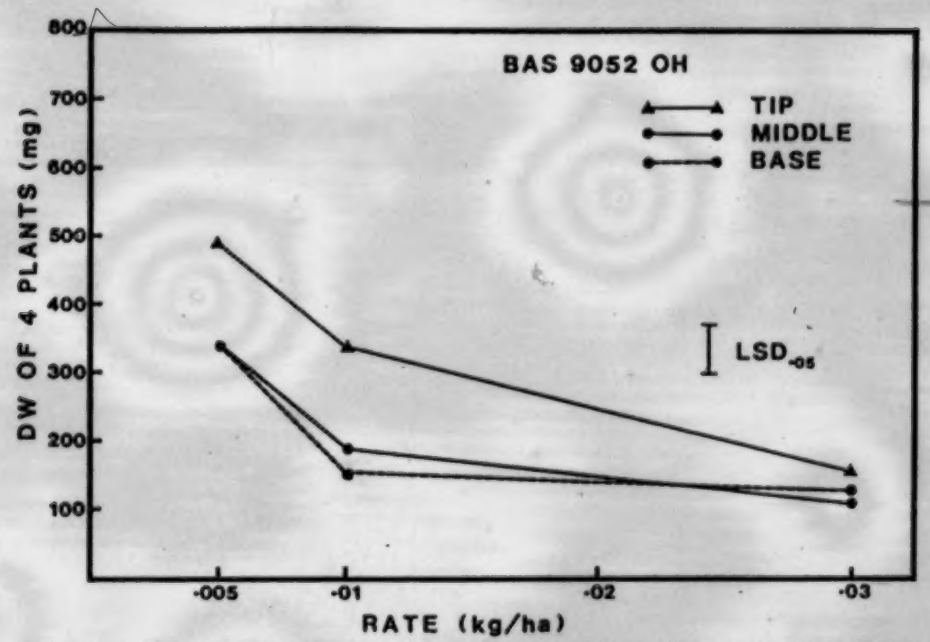


Figure 20. Effect of site of application of BAS 9052 OH on the dry weight of green foxtail plants, 15 days after treatment.
(DW of control plants at harvest was 680 mg)

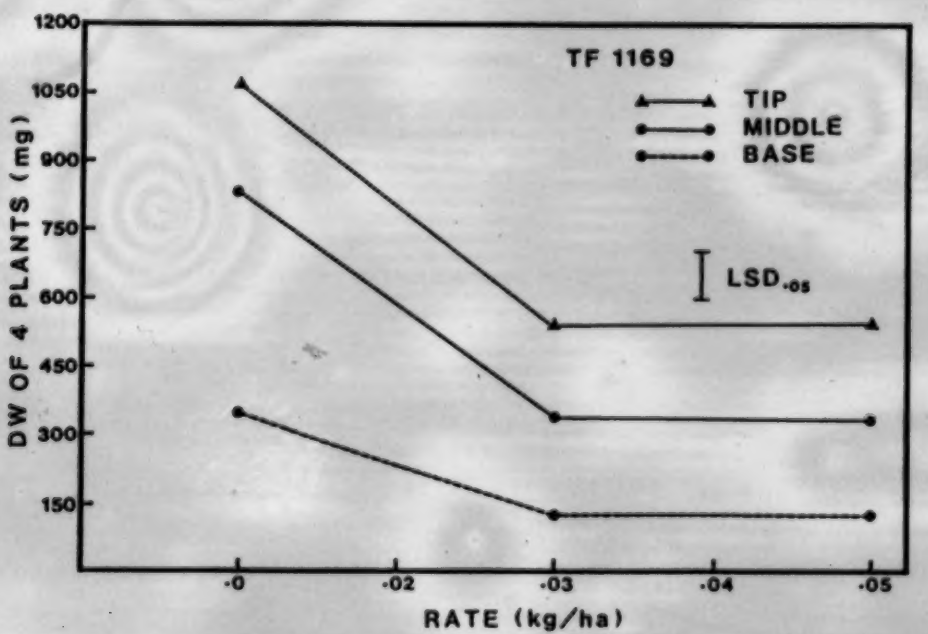


Figure 21. Effect of site of application of TF 1169 on the dry weight of green foxtail plants, 15 days after treatment.
(DW of control plants at harvest was 996 mg)

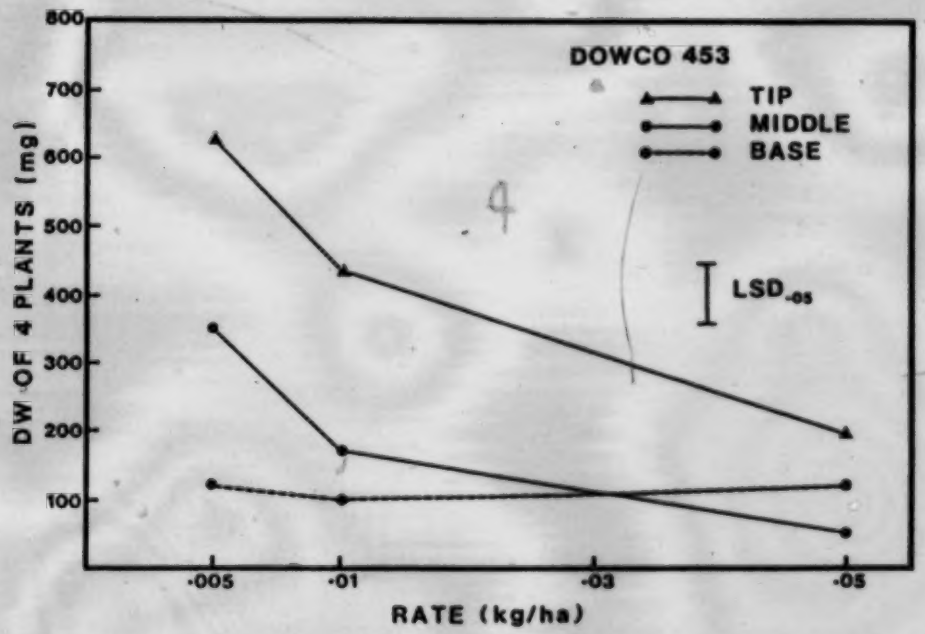


Figure 22. Effect of site of application of DOWCO 453 on the dry weight of green foxtail plants, 15 days after treatment.
(DW of control plants at harvest was 771 mg)

All treatments with DOWCO 453 also resulted in significantly lower dry weight of green foxtail plants than the controls, 15 days after treatment. At the lowest concentration, treatment at the base of the leaf blade was most effective while treatment at the tip of the leaf blade was least effective in inhibiting growth. At the highest concentration, treatments at the tip or middle of the leaf blade were not significantly different from the treatments at the base of the leaf blade (Figure 22).

The activity of all three herbicides generally was increased as the herbicide was applied closer to the leaf base, the application between the leaf sheath and the stem being the most effective. A similar increase in

effectiveness has been reported for barban (34,96), benzoylprop ethyl and difenzoquat'' (34) in wild oats when the herbicide was applied nearer the leaf or plant base. It has been suggested that this could be a function of placing the chemical nearer to its site of action, thus minimizing any limiting factors associated with transport (34). The site of action of BAS 9052 OH, TF 1169, and DOWCO 453 in wild oats and possibly in green foxtail appears to be near the base of the rapidly elongating internodes. The injury symptoms observed on wild oat and green foxtail plants following spot applications were similar to those observed with spray applications with the herbicides. This indicated that the herbicides probably were translocated from the site of application on the leaf to the site of action in the stem in wild oat and green foxtail plants. Hence, like in the case of other wild oat herbicides, the decrease in the activity of the herbicides, especially TF 1169, as a result of their placement away from the site of action may be associated with the distance the herbicides have to travel to reach the site of action. This appears to be particularly true in wild oats where the leaves are much longer than in green foxtail.

Penetration of the herbicides at different sites on the leaf also may affect their activity on plants. The plant cuticle and the amount and type of epicuticular wax are important factors which can affect leaf wettability and

---

''1,2-dimethyl-3,5-diphenyl-1*H* -pyrazolium methyl sulphate.

subsequent penetration (22). Coupland et al. (34) showed that surface wax morphology varied considerably between different areas on the leaf of wild oats. The inner surface of the leaf sheath had little wax and the area immediately adjacent to the ligule had less wax than the rest of the leaf blade (34). This probably was a contributing factor to increased performance of BAS 9052 OH, TF 1169, and DOWCO 453 when they were placed closer to the leaf base. The effect of placing the herbicides, especially TF 1169, farther away from the leaf base was more drastic in wild oats than in green foxtail, possibly due to differences in the morphology and the amount and kind of leaf waxes in the two species.

The microclimate around the leaf base also may have been responsible for the increased effectiveness of the herbicides placed around this region. Humidity, which can affect the time for herbicide solution on the leaf to dry, tends to be higher near the leaf base than at the leaf tip (34).

4.7.3 Mutilation studies on wild oats

Wild oat plants at the 3-leaf stage were treated at the middle of the second leaf blade with two concentrations of BAS 9052 OH, TF 1169 or DOWCO 453. Herbicide emulsions were applied as single 8-µl droplets and the treated leaf was removed from the base of the leaf blade after intervals of 2 to 36 hours. In one treatment, the treated leaf was not removed until harvest, 15 days after treatment. Experiments

were conducted separately for each herbicide.

Dry weights of plants treated with BAS 9052 OH were significantly lower than the untreated control when the treated leaf was allowed to remain on the plant for 4 to 6 hours. The plants were not killed, however, unless the treated leaf was allowed to remain on the plant for at least 8 hours at the higher rate or 10 hours at the lower rate.

Dry weights of wild oat plants treated with TF 1169 were significantly lower than the untreated control when the treated leaf was allowed to remain on the plant for 4 hours. The plants were not killed by any of the treatments except when the treated leaf was allowed to remain on the plant until harvest, 15 days after treatment at the higher rate. The plants showed stunting and crinkling symptoms on the young leaves 4 days after treatment but they recovered and resumed growth after this initial suppression even when the treated leaf was allowed to remain on the plant for 36 hours.

Dry weight data of wild oat plants treated with DOWCO 453 showed variability when the treated leaf was removed 6 hours after treatment or earlier. Visual observations indicated that growth of the plants was affected when the treated leaf was allowed to remain on the plant for 8 to 10 hours. The plants were killed when the treated leaf was allowed to remain intact until 24 hours after treatment at the higher rate or 36 hours after treatment at the lower rate.

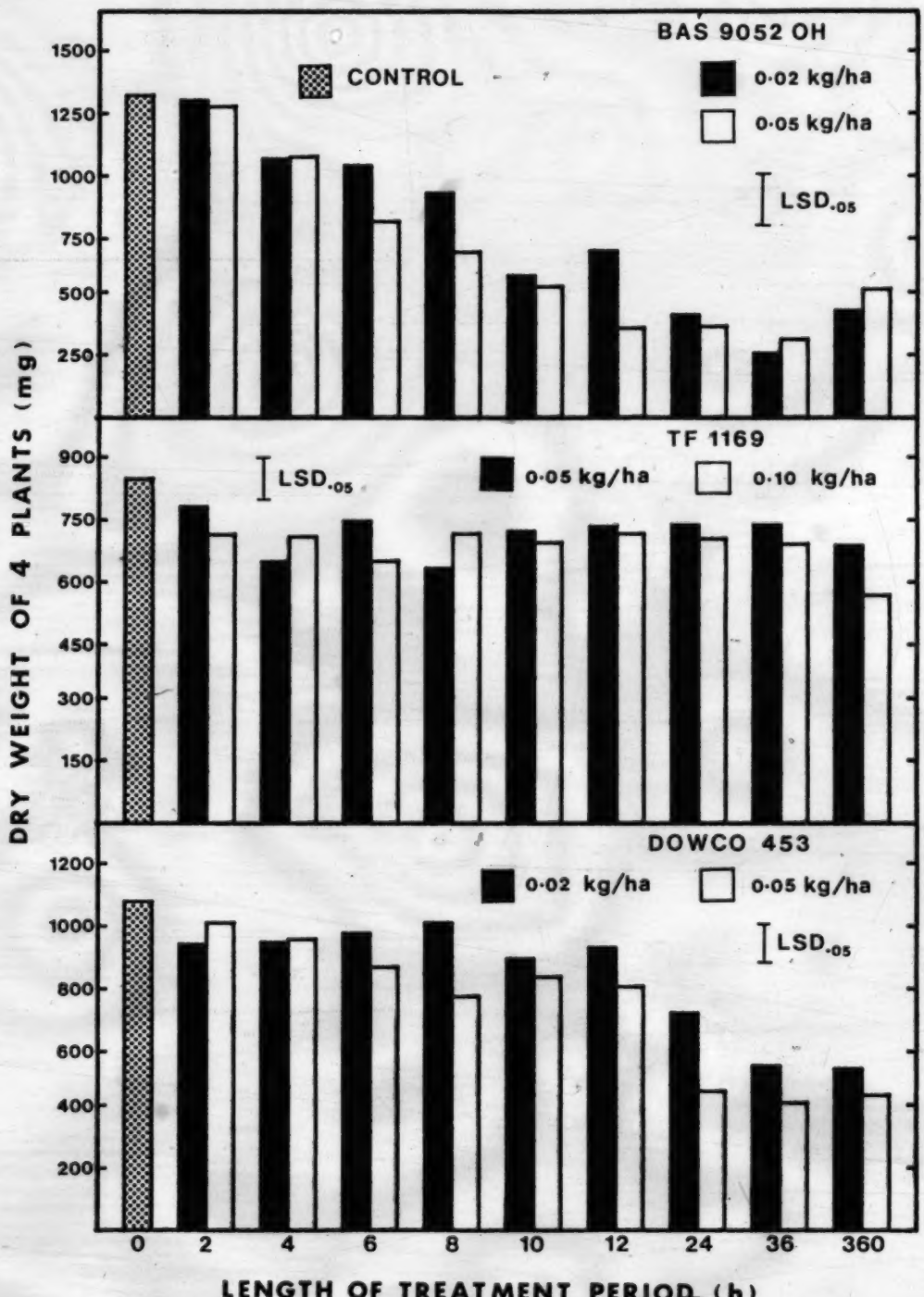


Figure 23. Effect of different periods of treatment with BAS 9052 OH, TF 1169 or DOWCO 453 on the dry weight of wild oat plants, 15 days after treatment.

The effect of single leaf application of the herbicides on the growth of wild oat plants indicated that the herbicides were translocated from the treated leaf to the site of action in the stem. Of the three herbicides, BAS 9052 OH appeared to be the fastest acting one, with a sufficient amount moving out of the treated leaf within 10 hours of application to kill the plant. TF 1169 was less effective even when the treated leaf was not removed until 36 hours after treatment. The droplets were applied on the leaf blade about 3 to 4 cm away from the base. In site of application studies, it became clear that TF 1169 lost its effectiveness on wild oats when it was applied away from the base of the leaf blade. Hence, the lower activity of TF 1169 in mutilation experiments may have been more a function of site of application than of the time for the herbicide to remain on the plant. In studies in which TF 1169 was sprayed over the whole plant and the plants were subjected to simulated rainfall, the activity of the herbicide was not appreciably decreased by rainfall even 1 hour after treatment (106). The activity of DOWCO 453 was not reduced when the treated leaf was removed from the rest of the plant 36 hours after treatment. Apparently sufficient herbicide was absorbed and translocated out of the treated leaf to the site of action in plants within 36 hours of application.

My results indicated that the slow absorption and translocation of these herbicides may be directly responsible for their slow action. BAS 9052 OH showed a more

rapid movement from the treated leaf than TF 1169 or DOWCO 453. This difference is consistent with the timing of appearence of injury symptoms (constriction) on the stem of wild oats.

4.8 Viability of Quackgrass Rhizomes

Shoots growing from the proximal end node of rhizome sections with ten nodes each were treated with three rates of BAS 9052 OH, TF 1169 or DOWCO 453, at the 3- or 5-leaf stage of the plants. The shoots were clipped at soil level 15 days after treatment and their dry weights were obtained, and each node of the rhizome segments then was replanted individually to examine the effect of the herbicide treatment on their viability.

All herbicide treatments except the lowest rate of BAS 9052 OH resulted in a significantly lower dry weight of quackgrass shoots 15 days after treatment at both stages of growth (Table 17). The shoots were severely chlorotic at the highest rate of BAS 9052 OH or TF 1169 and the two higher rates of DOWCO 453.

Table 17. **Dry weight of quackgrass shoots 15 days after treatment.**

Treatment†	Rate kg/ha	Quackgrass shoots			
		3 LS		5 LS	
		Score‡	D.W.‡ (%)	Score‡	D.W.‡ (%)
Control		0	100	0	100
BAS 9052 OH	0.05	4	80	3	97
BAS 9052 OH	0.10	6	60	6	62
BAS 9052 OH	0.15	8	24	8	44
L.S.D. (0.05)			25		25
Control		0	100	0	100
TF 1169	0.05	6	49	4	73
TF 1169	0.10	7	62	5	62
TF 1169	0.15	8	10	7	32
L.S.D. (0.05)			24		24
Control		0	100	0	100
DOWCO 453	0.03	6	47	5	79
DOWCO 453	0.05	9	8	9	16
DOWCO 453	0.10	9	24	9	8
L.S.D. (0.05)			19		19

†Experiments were conducted separately for each herbicide. LS refers to leaf stage of quackgrass shoots at the time of spray.
‡Visual ratings were done at the time of harvesting 15 days after treatment. Dry weights are expressed as percent of control.

All treatments with BAS 9052 OH significantly reduced the viability of quackgrass rhizome nodes (Table 18). At the highest rate of the herbicide, applications at the advanced growth stage of quackgrass shoots were more effective in reducing the viability than applications at the early growth stage. The nodes that were prevented from sprouting were located at random on the rhizome segments.

Table 18. Viability of individual quackgrass rhizome nodes after treatment of the shoots with BAS 9052 OH.

Treatment†	Rate kg/ha	Number of nodes sprouted‡ Node position on rhizome 1	2	3	4	5	6	7	8	9	10	Mean
Control		4	3	3	4	3	2	4	3	4	0	3.0 a
BAS 9052 OH	0.05	2	2	4	2	2	0	4	3	1	0	1.9 bc
BAS 9052 OH	0.10	2	2	3	4	3	0	0	2	0	0	1.6 c
BAS 9052 OH	0.15	2	2	2	2	2	2	1	1	0	0	1.4 c
Control		3	4	4	3	2	4	3	3	1	1	2.8 ab
BAS 9052 OH	0.05	2	1	3	3	3	2	0	2	1	0	1.7 c
BAS 9052 OH	0.10	3	0	2	2	1	0	1	0	1	1	1.1 c
BAS 9052 OH	0.15	1	0	1	1	0	1	0	0	0	0	0.4 d

†The top four treatments were applied at the 3-leaf stage and the bottom four treatments were applied at the 5-leaf stage of quackgrass plants.
‡The data represent the total number of nodes sprouted at each node position on the rhizome in all the replicates of each treatment. Position 1 represents the proximal end node on the rhizome segments.
Means followed by the same letter are not significantly different as determined by L.S.D. values at $P \leq 0.05$. Analysis of variance was done on transformed data.

Treatments with TF 1169 at the two higher rates significantly reduced the viability of quackgrass rhizome nodes (Table 19). The efficacy of TF 1169 for reducing the viability of rhizome nodes was not affected by the stage of growth of quackgrass shoots at the time of treatment. The nodes that showed no sprouting were located randomly on the rhizome segments.

Table 19. **Viability of individual quackgrass rhizome nodes after treatment of the shoots with TF 1169.**

Treatment†	Rate kg/ha	Number of nodes sprouted‡ Node position on rhizome 1	2	3	4	5	6	7	8	9	10	Mean
Control		3	3	4	4	3	2	2	3	3	2	2.9 ab
TF 1169	0.05	2	3	2	2	2	3	3	2	3	3	2.5 ab
TF 1169	0.10	2	1	2	0	2	3	2	0	2	2	1.6 cd
TF 1169	0.15	2	1	2	2	0	2	1	2	1	0	1.3 d
Control		4	4	3	3	2	3	4	2	3	3	3.1 a
TF 1169	0.05	4	3	4	4	3	2	3	3	3	2	3.1 a
TF 1169	0.10	3	2	3	3	2	2	3	2	1	1	2.2 bc
TF 1169	0.15	0	2	3	2	2	0	2	0	1	0	1.2 d

†The top four treatments were applied at the 3-leaf stage and the bottom four treatments were applied at the 5-leaf stage of quackgrass plants.
‡The data represent the total number of nodes sprouted at each node position on the rhizome in the four replicates of each treatment. Position 1 represents the proximal end node of the rhizome segments.
Means followed by the same letter are not significantly different as determined by L.S.D. values at $P \leq 0.05$. Analysis of variance was done on transformed data.

Treatments with DOWCO 453 at the two higher rates resulted in a significant reduction in viability of the rhizome nodes (Table 20). Treatments applied at the advanced growth stage of quackgrass shoots were more effective in reducing the viability of rhizome nodes than treatments applied at the early growth stage of the shoots. The nodes that did not sprout were located at random on the rhizome segments.

Table 20. Viability of individual quackgrass rhizome nodes after treatment of the shoots with DOWCO 453.

Treatment†	Rate kg/ha	Number of nodes sprouted‡ Node position on rhizome 1	2	3	4	5	6	7	8	9	10	Mean
Control		4	4	4	3	4	3	3	3	4	2	3.4 a
DOWCO 453	0.03	3	3	3	4	2	3	2	3	2	1	2.6 ab
DOWCO 453	0.05	2	2	3	2	0	1	2	2	0	1	1.5 bc
DOWCO 453	0.10	2	1	2	1	1	2	0	2	0	1	1.2 c
Control		4	3	4	4	4	3	2	4	4	2	3.4 a
DOWCO 453	0.03	3	4	4	3	3	4	2	2	3	2	3.0 a
DOWCO 453	0.05	0	1	3	1	2	0	2	1	0	2	1.2 c
DOWCO 453	0.10	0	0	0	0	0	0	0	0	0	0	0.0 d

†The top four treatments were applied at the 3-leaf stage and the bottom four treatments were applied at the 5-leaf stage of quackgrass plants.
‡The data represent the total number of nodes sprouted at each node position on the rhizome in the four replicates of each treatment. Position 1 represents the proximal end node of the rhizome segments.
Means followed by the same letter are not significantly different as determined by L.S.D. values at $P \leq 0.05$.
Analysis of variance was done on transformed data.

The reduction in the viability of quackgrass rhizome nodes following foliar applications of the herbicides probably is a function of translocation of the herbicides from the shoots to the rhizome system in sufficient amounts to prevent sprouting. BAS 9052 OH and TF 1169 have been observed to translocate readily from shoots to rhizomes in quackgrass (37,81). The higher activity of BAS 9052 OH and DOWCO 453 following foliar applications at the advanced growth stage may have been due to more rapid translocation of the herbicides from the shoots to the rhizomes. It has been reported that quackgrass shoots exported more

assimilates to the rhizomes after they reached the 4-leaf stage of growth (53,111).

BAS 9052 OH and TF 1169 did not prevent sprouting from all the nodes on the segments at the rates applied. The nodes that were prevented from sprouting were located randomly on the rhizome segments. This may be due to the fact that the nodes that were metabolizing actively and thus were acting as a sink at the time of herbicide application, probably were killed as a consequence of more accumulation of the herbicides than the nodes that were dormant. Fragmentation of the rhizomes has been reported to release the nodes from dormancy (62,70,129). Hence, the nodes that escaped the phytotoxic effects of the herbicides on the intact rhizome gave rise to shoots after they were fragmented and planted individually. Higher rates of the herbicides, however, may inhibit sprouting from all nodes on the rhizome as is evident from DOWCO 453 treatments.

4.9 Herbicide Mixtures

4.9.1 Mixtures with other wild oat herbicides

The efficacy of BAS 9052 OH applied in combination with other postemergence herbicides for wild oat control in rapeseed was evaluated in the field during 1980. BAS 9052 OH applied alone at 0.25 kg/ha provided excellent control of wild oats at the 3-leaf stage. The two lower rates were less effective (Table 21).

Table 21. **Mixtures of BAS 9052 OH with other herbicides for wild oat control in rapeseed.**

Treatment†	Rate kg/ha	Wild oats Score Aug 6	Wild oats Culms /m²‡	Wild oats D.W. g/m²‡	Rape Score Aug 6	Rape Yield g/m²‡
Weedy check		0	541 a	598 a	9	44 a
BAS 9052 OH	0.10	7	166 c-e	106 cd	9	114 bc
BAS 9052 OH	0.15	5	288 bc	165 c	9	115 bc
BAS 9052 OH	0.25	9	1 e	1 e	9	109 bc
BAS9052+Barb	0.10+0.20	7	219 cd	67 de	9	103 b
BAS9052+Barb	0.15+0.20	8	106 de	33 de	9	96 b
Barban	0.40	7	154 c-e	89 c-e	9	127 bc
BAS9052+DCM	0.10+0.40	9	5 e	1 e	9	130 bc
BAS9052+DCM	0.15+0.40	9	1 e	1 e	9	154 c
Diclofop	0.70	8	76 de	17 de	9	155 c
BAS9052+BPE	0.10+0.70	8	45 e	19 de	9	123 bc
BAS9052+BPE	0.15+0.70	9	37 e	7 de	9	139 bc
Benzoylprop	1.40	4	418 ab	319 b	8	33 a
TF 1169	0.30	9	8 e	1 e	9	153 c

†Barb=barban, DCM=diclofop=diclofop methyl, BPE=benzoyl prop ethyl.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Mixtures of BAS 9052 OH at the two low rates with barban or diclofop methyl, also at low rates, provided the same level of wild oat control as that obtained with high rates of barban, diclofop methyl or BAS 9052 OH. Mixtures of BAS 9052 OH with benzoylprop ethyl resulted in a significant increase in the level of wild oat control over that obtained with benzoylprop ethyl applied alone. TF 1169 was as effective as BAS 9052 OH applied alone at 0.25 kg/ha (Table 21).

All herbicide treatments, except benzoylprop ethyl applied alone, resulted in significantly increased rapeseed yields. Benzoylprop ethyl treatment resulted in both poor weed control and injury to rapeseed plants.

In general, mixtures of BAS 9052 OH with barban, diclofop methyl or benzoylprop ethyl demonstrated good compatibility. The application of BAS 9052 OH in mixtures with barban can result in an increase in the flexibility of application timing since barban when applied alone shows maximum activity at the 2-leaf stage of wild oats. Mixtures of BAS 9052 OH with barban or benzoylprop ethyl also could result in broad-spectrum grass weed control since barban and benzoylprop ethyl are effective only against wild oats. Benzoylprop ethyl applied alone was less effective on wild oats than the other herbicides, and can cause injury to rapeseed. Mixtures of BAS 9052 OH with benzoylprop ethyl can provide good control of wild oats without causing injury to crop plants.

4.9.2 Grass weed control with DOWCO 290 mixtures

Green foxtail was very sensitive to competition from the crop; as a result, dry weights of green foxtail in weedy check plots were considerably lower in crop than without crop. BAS 9052 OH or DOWCO 453 in combination with DOWCO 290 was very effective in controlling green foxtail, both in crop and without crop. TF 1169 or diclofop methyl in mixture with DOWCO 290 was less effective (Table 22).

Table 22. **Herbicide mixtures with DOWCO 290 for green foxtail control without crop and in crop.**

		Green foxtail		
		Without crop		In crop
Treatment†	Rate kg/ha	Score	Dry wt. g/m²‡	Dry wt. g/m²‡
Weedy check		0	701 a	38 a
Diclofop methyl	0.70	6	257 cd	4 d
HOE 00654	0.35	4	391 bc	4 d
HOE 00654	0.45	6	183 d	3 d
BAS9052+DWC290	0.25+0.30	9	10 e	0 d
TF1169 +DWC290	0.35+0.30	4	386 bc	14 b
DWC453 +DWC290	0.15+0.30	9	0 e	1 d
Diclof.+DWC290	0.70+0.30	2	459 b	12 bc
Trifluralin[PPI]	1.10	6	259 cd	5 cd

†DWC453=DOWCO 453, DWC290=DOWCO 290, Diclof.=diclofop methyl. HOE 00654 is a stereoisomer of diclofop methyl. Trifluralin was applied pre-plant incorporated to the soil. All other treatments were applied at the 3-leaf stage of green foxtail.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

All herbicide treatments were very effective in controlling wild oats in crop (Table 23). Trifluralin was

ineffective without crop. Visual observations indicated that the level of wild oat control obtained with diclofop methyl alone was decreased when diclofop methyl was applied in combination with DOWCO 290. Rapeseed yields in the herbicide-treated plots did not differ significantly from those in the weedy check.

Table 23. **Herbicide mixtures with DOWCO 290 for wild oat control without crop and in crop.**

		Wild oats					Rape
		Without crop		In crop			
Treatment†	Rate kg/ha	Score	Culms /m²‡	D.W. g/m²‡	Culms /m²‡	D.W. g/m²‡	Yield g/m²‡
Weedy check		0	653 a	673 a	295 a	142 a	163
Diclofop meth.	0.70	9	21 c	41 b	0 c	0 b	214
HOE 00654	0.35	8	16 c	16 b	4 c	1 b	209
HOE 00654	0.45	9	16 c	11 b	0 c	0 b	214
BAS9052+DWC290	0.25+0.30	9	8 c	7 b	0 c	0 b	212
TF1169 +DWC290	0.35+0.30	8	21 c	22 b	0 c	0 b	193
DWC453 +DWC290	0.15+0.30	9	0 c	0 b	0 c	0 b	225
Diclof.+DWC290	0.40+0.30	7	82 c	83 b	12 c	3 b	195
Trifluralin[PPI]	1.10	4	382 b	666 a	79 b	30 b	202

†DWC453=DOWCO 453, DWC290=DOWCO 290, Diclof.=diclofop methyl. HOE 00654 is a stereoismer of diclofop methtyl. Trifluralin was applied pre-plant incorporated to the soil. All other treatments were applied at the 3-leaf stage of wild oats.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

BAS 9052 OH, TF 1169 or DOWCO 453 in combination with DOWCO 290 provided excellent control of volunteer barley, both in crop and without crop. Diclofop methyl alone and in combination with DOWCO 290, HOE 00654, and trifluralin were

ineffective against barley (Table 24).

Table 24. **Herbicide mixtures with DOWCO 290 for volunteer barley control without crop and in crop.**

Treatment†	Rate kg/ha	Volunteer barley					
		Without crop			In crop		
		Score	Culms /m²‡	D.W. g/m²‡	Culms /m²‡	D.W. g/m²‡	
Weedy check		0	410 a	931 ab	223 abc	380 a	
Diclofop meth.	0.70	0	389 a	791 b	194 bc	292 a	
HOE 00654	0.35	0	433 a	980 a	257 a	404 a	
HOE 00654	0.45	0	414 a	938 ab	209 bc	328 a	
BAS9052+DWC290	0.25+0.30	9	3 b	5 c	0 d	0 b	
TF1169 +DWC290	0.35+0.30	9	2 b	5 c	1 d	1 b	
DWC453 +DWC290	0.15+0.30	9	0 b	0 c	0 d	0 b	
Diclof.+DWC290	0.70+0.30	0	408 a	885 ab	238 ab	382 a	
Trifluralin[PPI]	1.10	0	370 a	812 b	188 c	296 a	

†DWC453=DOWCO 453, DWC290=DOWCO 290, Diclof.=diclofop methyl. HOE 00654 is a stereoisomer of diclofop methyl. Trifluralin was applied pre-plant incorporated to the soil. All other treatments were applied at the 5-leaf stage of volunteer barley.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

The results of the field experiments with mixtures of BAS 9052 OH, TF 1169 or DOWCO 453 with DOWCO 290 confirmed the reports of earlier experiments by other workers (47,49,50). BAS 9052 OH or DOWCO 453 in mixture with DOWCO 290 provided excellent control of all three grass weeds. The activity of TF 1169 in combination with DOWCO 290 appeared to be slightly reduced on green foxtail but not on wild oats or volunteer barley. Contrary to some reports (4,49,50), however, no injury to rapeseed was observed from any of the

herbicide mixtures.

Mixtures of BAS 9052 OH, TF 1169 or DOWCO 453 with DOWCO 290 performed better than the mixture of diclofop methyl and DOWCO 290 and the pre-plant incorporated treatment of trifluralin. The new grass herbicides applied in combination with DOWCO 290 may provide a useful means to achieve broad-spectrum grass and broad-leaved weed control in a single application.

5. CONCLUSION

Results of field and greenhouse experiments indicated that the three new herbicides, BAS 9052 OH, TF 1169, and DOWCO 453, were highly effective in controlling wild oats, green foxtail, and volunteer barley at a range of growth stages. BAS 9052 OH was most effective on green foxtail and wild oats and somewhat less effective on volunteer barley. TF 1169 was most effective on wild oats and volunteer barley and somewhat less effective on green foxtail. DOWCO 453 was very effective on all three annual grasses. Rapeseed showed a high level of tolerance to all three herbicides at all stages of growth tested.

Efficacy of the new herbicides was affected in some instances by the growth stage of the grass weeds at the time of application. With some exceptions, the herbicides inhibited growth of weeds faster when they were applied at the early growth stage than at the advanced growth stage. The efficacy of BAS 9052 OH on wild oats was significantly greater when it was applied at the 2-leaf stage than at the 4-leaf stage. Conversely, its efficacy on barley was significantly lower at the 2-leaf stage than at the 4-leaf stage. TF 1169 was considerably less effective at the 4-leaf stage than at the 2-leaf stage of green foxtail. DOWCO 453 was equally effective at all stages of growth of the weeds tested. It is suggested that applications of these herbicides at an early (2- to 3-leaf) growth stage of weeds could prove advantageous in timely and faster elimination of

weed competition.

BAS 9052 OH at a reduced rate applied in combination with other herbicides such as barban, diclofop methyl, or benzoylprop ethyl also at reduced rates, provided as effective control of wild oats in rapeseed as when the herbicide was applied alone at the full rate. Combination of BAS 9052 OH with benzoylprop ethyl also proved to be safer on rapeseed than benzoylprop ethyl alone.

The efficacy of BAS 9052 OH, TF 1169, and DOWCO 453 for grass weed control was not significantly reduced when any one of these herbicides was applied in combination with DOWCO 290, a herbicide for broad-leaved weed control in rapeseed. Tank-mix applications of BAS 9052 OH, TF 1169, or DOWCO 453 with DOWCO 290 could provide a useful method to control grass weeds as well as various broad-leaved weeds in a single application.

BAS 9052 OH, TF 1169, and DOWCO 453 affected the young growing tissue of grasses. Herbicide injury symptoms were characterized by inhibition of growth and chlorosis at the base of the youngest leaf and were visible 3 to 4 days after herbicide application. Rapidly elongating internodes showed a marked constriction near the base within 2 days of treatment with TF 1169 or DOWCO 453. Wild oat plants at the 5-leaf stage showed that the fourth internode which was about 2 mm in length at the time of treatment, was most severely affected. Histological studies on wild oat stem sections taken from near the base of this internode

indicated that the herbicides inhibited lateral expansion and elongation of cells in the cortex and ground parenchyma regions. Inhibition of cell elongation, however, was less severe than inhibition of internode elongation. Since both cell elongation and cell division contribute to stem elongation in early stages of internode development, it is proposed that BAS 9052 OH, TF 1169, and DOWCO 453 affect growth in grasses predominantly by inhibiting cell elongation and cell division in rapidly elongating internodes.

Besides affecting cell division and cell elongation, the herbicides disrupted the anatomical structure of wild oat stem tissue. Epidermis and cortical parenchyma cells were most severely affected. Cells of the procambium between the xylem and the phloem were killed. Metaxylem and metaphloem were obliterated and the tissue near the base of the fourth internode was killed within 14 days of treatment. This coincided with the death of the whole plant following severe chlorosis and tissue desiccation.

The main site of action of BAS 9052 OH, TF 1169, and DOWCO 453 in grasses such as wild oats and green foxtail appears to be near the base of the rapidly elongating internodes. The herbicides showed increased activity as they were applied closer to the leaf base. Single droplet applications between the leaf sheath and the stem were most effective while applications to the leaf tip were least effective in inhibiting growth. The effect of leaf

application of these herbicides on the growth of plants suggested that BAS 9052 OH, TF 1169, and DOWCO 453 probably were translocated from the site of application on the leaves to the site of action in the stem.

Some differences were observed in the translocation characteristics of the three grass herbicides in wild oats and green foxtail. The activity of BAS 9052 OH and DOWCO 453 was affected to a lesser extent by site of application on wild oats than the activity of TF 1169. Similar results were observed on green foxtail. The activity of TF 1169, however, was affected much less by site of application on green foxtail than on wild oats. This probably was due to much shorter leaves of green foxtail than those of wild oats and differences in the amount and morphology of leaf waxes in the two species. The low susceptibility of green foxtail to TF 1169 applications, however, is difficult to explain on the basis of my results.

BAS 9052 OH produced a faster response in wild oats than TF 1169 or DOWCO 453. The leaf treated with BAS 9052 OH had to remain attached to the rest of the untreated plant for 10 hours to kill the plants. DOWCO 453 required 36 hours to produce the same effect. TF 1169 did not kill the plants even when the treated leaf was not removed from the rest of the plant until after 36 hours. These results indicated that the time required for BAS 9052 OH to move out of the treated leaf of wild oats in sufficient amounts to kill the plants was much less than that for DOWCO 453 or TF 1169. This

probably is the reason for BAS 9052 OH to show injury symptoms (constriction) near the base of the internode much earlier than the other two herbicides.

In the field, BAS 9052 OH and TF 1169 did not provide satisfactory control of established quackgrass at the rates tested. These herbicides, although they were effective in controlling growth from planted rhizomes, did not adequately prevent regrowth in the year after application. DOWCO 453 at rates as low as 0.35 kg/ha was very effective on quackgrass grown from planted rhizomes. All treatments with this herbicide also prevented quackgrass regrowth in the next growing season. No adverse effect was observed on barley seeded in the herbicide-treated plots in the year following herbicide application.

In the greenhouse, all three herbicides were very effective in controlling quackgrass and preventing regrowth from the rhizomes. Herbicides applied to the shoot at one end of rhizome sections consisting of 10 nodes inhibited sprouting from most of the nodes on the rhizome section. DOWCO 453 was more effective in inhibiting sprouting from the nodes than BAS 9052 OH or TF 1169.

The poor control of quackgrass with BAS 9052 OH or TF 1169 in the field was probably due to the rates of the herbicides applied being too low. Further experiments with these herbicides would be required to establish rates which are effective for the control of established quackgrass in the field. Application of BAS 9052 OH or TF 1169 coupled

with various cultivation methods may improve control of established quackgrass with these herbicides. Planting of competitive crops such as rapeseed in the year of herbicide application and barley one year after herbicide application may help to suppress the recovery of quackgrass plants from herbicide injury and regrowth from rhizomes. The new herbicides can provide a substitute for non-selective herbicides such as glyphosate for quackgrass control and thus can eliminate the need for fallowing for control of this weed.

BIBLIOGRAPHY

1. Alex, J.F. 1966. Survey of weeds of cultivated land in the prairie provinces. Research Branch, Agriculture Canada, Regina, Sask. 68 pp.

2. Alex, J.F., J.D. Banting, and J.P. Gebhardt. 1972. Distribution of *Setaria viridis* in Western Canada. Can. J. Plant Sci. 52:129-138.

3. Anonymous. 1981. POAST. Technical information bulletin. BASF Canada Inc., Rexdale, Ontario. 5 pp.

4. Anonymous. 1980. TF 1169, experimental herbicide. Technical information, Chipman Inc., Winnipeg, Manitoba. 5 pp.

5. Anonymous. 1981. DOWCO 453 herbicide. Information bulletin. Dow Chemical of Canada Ltd., Edmonton, Alta. 3 pp.

6. Anonymous. 1982. DOWCO 453ME, experimental herbicide. Technical information. Dow Chemical U.S.A., Midland, Michigan, 4 pp.

7. Asare-Boamah, N.K. and R.A. Fletcher. 1982. Phytotoxicity of sethoxydim on corn seedlings. Abstr. Weed Sci. Soc. Amer. p. 90.

8. Baird, D.D. and G.F. Begeman. 1972. Postemergence characterization of a new quackgrass herbicide. Proc. Northeast. Weed Sci. Soc. 26:100-103.

9. Banting, J.D. 1962. The dormancy behaviour of *Avena fatua* L. in cultivated soil. Can. J. Plant Sci. 42:22-39.

10. Banting, J.D. 1966. Studies on the persistence of *Avena fatua*. Can. J. Plant Sci. 46:129-140.

11. Banting, J.D. 1966. Factors affecting the persistence of *Avena fatua*. Can. J. Plant Sci. 46:469-478.

12. Banting, J.D. 1977. Growth habit and control of wild oats. Can. Dept. of Agric., Ottawa, Ontario. Publ. 1531. 44 pp.

13. Bell, A.R. and J.D. Nalewaja. 1968. Competitive effects of wild oats in flax. Weed Sci. 16:501-504.

14. Bell, A.R. and J.D. Nalewaja. 1968. Competition of wild oat in wheat and barley. Weed Sci. 16:505-509.

15. Berlyn, G.P. and J.P. Miksche. 1976. Botanical Microtechnique and Cytochemistry. The Iowa State University Press, Ames, Iowa. 326 pp.

16. Blackshaw, R.E., E.H. Stobbe, C.F. Shaykewich, and W. Woodbury. 1981. Influence of soil temperature and soil moisture on green foxtail (*Setaria viridis*) establishment in wheat (*Triticum aestivum*). Weed Sci. 29:179-184.

17. Blackshaw, R.E., E.H. Stobbe, and A.R.W. Sturko. 1981. Effect of seeding dates and densities of green foxtail (*Setaria viridis*) on the growth and productivity of spring wheat (*Triticum aestivum*). Weed Sci. 29:212-217.

18. Blair, A.M. and J. Holroyd. 1970. Herbicides for the control of *Agropyron repens* and *Agrostis gigantea*. Proc. British Weed Cont. Conf. 10:326-330.

19. Bonnett, O.T. 1961. The oat plant: Its histology and development. University of Illinois, Agric. Exp. Sta., Bulletin 672:27-35.

20. Bowden, B.A. and G. Friesen. 1967. Competition of wild oats (*Avena fatua* L.) in wheat and flax. Weed Res. 7:349-359.

21. Bridges, D.C., T. Whitewell, and R.H. Walker. 1981. Johnsongrass control in soybeans with postemergence herbicides. Proc. South. Weed Sci. Soc. 34:50.

22. Bukovac, M.J. 1976. Herbicide entry into plants. *In:* L.J. Audus, ed. Herbicide: Physiology, Biochemistry, Ecology. Academic Press, London, Vol.1. pp. 355-364.

23. Campbell, J.R. and D. Penner. 1981. Absorption and translocation of BAS 9052 OH [2-(1-(ethoxyimino) -butyl)-5-(2-(ethylthio)-propyl) -3-hydroxy -2-cyclohexane-1-one]. Abstr. Weed Sci. Soc. Amer. p. 108.

24. Canada Weed Committee. 1974. Research Report - Western section. 496 pp.

25. Casely, J. 1972. The effect of environmental factors on the performance of glyphosate against *Agropyron repens*. Proc. British Weed Cont. Conf. 11:641-647.

26. Cerdeira, A.L. and E. Voll. 1981. Efficacy and phytotoxicity of post-emergent herbicides to control grasses in soybeans (*Glycine max*). Weed Abstr. 30(10):393.

27. Chandler, J.M. and R.N. Paul. 1982. Effect of sethoxydim and light level on the vascular bundle anatomy and ultrastructure of bermudagrass (*Cynodon dactylon* (L.) Pers.). Abstr. Weed Sci. Soc. Amer. p. 84.

28. Chernicky, J.P., B.J. Gossett, and V.L. Quisenberry. 1981. Factors influencing the response of annual grasses to BAS 9052 and RO 13-8895. Proc. South. Weed Sci. Soc. 34:97.

29. Chow, P.N.P. 1982. Herbicidal activation of BAS 9052 OH with surfactants and additives for wild oat (*Avena fatua*) control. Abstr. Weed Sci. Soc. Amer. p. 17.

30. Chow, P.N.P. and D.G. Dorrel. 1979. Response of wild oats (*Avena fatua*), flax (*Linum utitatissimum*), and rapeseed (*Brassica campestris* and *B. napus*) to diclofop-methyl. Weed Sci. 27:212-215.

31. Coffman, C.B., J.R. Frank, and W.A. Gentner. 1982. Weed control in selected ornamentals and groundcovers with sethoxydim and oxyfluorfen. Abstr. Weed Sci. Soc. Amer. p. 35.

32. Colby, S.R., J.R. Bone, and A.A. Akhavein. 1982. PP 009, a selective herbicide for control of perennial and annual grasses. Abstr. Weed Sci. Soc. Amer. p. 14.

33. Colby, S.R., J.T. Daniel, and D.A. Thomas. 1982. Postemergence control of perennial grasses with sequential and single applications of PP 009. Abstr. Weed Sci. Soc. Amer. p. 16.

34. Coupland, D., W.A. Taylor, and J.C. Casely. 1978. The effect of site of application on the performance of glyphosate on *Agropyron repens* and barban, benzoylprop ethyl and difenzoquat on *Avena fatua*. Weed Res. 18:123-128.

35. Cussans, G.W. 1970. Biological background to the control of rhizomatous grasses. Proc. British Weed Cont. Conf. 10:1101-1107.

36. Cussans, G.W. and B.J. Wilson. 1970. Cultural and chemical treatments for the control of *Agropyron repens* and *Agrostis gigantea* in barley. Proc. British Weed Cont. Conf. 10:344-351.

37. Dekker, J.H. 1981. Regrowth and translocation in quackgrass (*Agropyron repens*) with several post-emergence herbicides. Abstr. Weed Sci. Soc. Amer. p. 107.

38. Dekker, J.H. and G.W. Anderson. 1982. Efficacy of several new postemergence grass herbicides. Abstr. Weed Sci. Soc. Amer. p. 128.

39. Devine, M.D. 1981. Glyphosate uptake, translocation and distribution in quackgrass (*Agropyron repens* (L.) Beauv.) and Canada thistle (*Cirsium arvense* (L.) Scop.). Ph.D. thesis, Univ. of Guelph, Guelph, Ontario. 108 pp.

40. Dew, D.A. and C.H. Keys. 1976. An index of competition for estimating loss of rape due to wild oats. Can. J. Plant Sci. 56:1005-1006.

41. Drew, B.N. 1982. Postemergence fluazofop-butyl for control of grasses in oilseeds and grain legumes. Abstr. Weed Sci. Soc. Amer. p. 113.

42. Donn, G. and H. Bieringer. 1980. The influence of temperature on the herbicidal activity of diclofop methyl against different weed grass species. Proc. British Crop Prot. Conf. - Weeds 15:283-288.

43. Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

44. Edwards, N.C., Jr. and H.R. Hurst. 1981. Over-the-top herbicides for annual grass control in soybeans. Proc. South. Weed Sci. Soc. 34:51.

45. Esau, K. 1957. Phloem degradation in Gramineae affected by barley yellow-dwarf virus. Amer. J. Bot. 44:245-251.

46. Esau, K. 1977. Anatomy of Seed Plants, Second Edition, John Willey & Sons, Santa Barbara. 550 pp.

47. Expert Committee on Weeds. 1981. Research Report - Eastern section. 456 pp.

48. Expert Committee on Weeds. 1979. Research Report - Western section. Vol. 1 and 2. 459 pp. and Vol. 3. 273 pp.

49. Expert Committee on Weeds. 1980. Research Report - Western section. Vol. 1 and 2. 621 pp. and Vol. 3. 130 pp.

50. Expert Committee on Weeds. 1981. Research Report - Western section. Vol. 1 and 2. 727 pp. and Vol. 3. 224 pp.

51. Fairbrothers, D.E. 1959. Morphological variations of *Setaria faberii* and *S. viridis*. Brittonia 11:44-48.

52. Finney, J.R. and P.B. Sutton. 1980. Planned grass weed control with fluazifop-butyl in broad-leaved crops. Proc. British Crop. Prot. Conf. - Weeds 15:429-436.

53. Fiveland, T.J., L.C. Erickson, and C.I. Seely. 1972. Translocation of ^{14}C-assimilates and 3-amino-1,2,4 -triazole and its metabolites in *Agropyron repens*. Weed Res. 12:155-163.

54. Friesen, G. 1967. The efficiency of barban as influenced by growth stage of wild oats and spring barley. Weeds 15:160-162.

55. Friesen, G. and L. Shebeski. 1960. Economic losses caused by weed competition in Manitoba grain fields. 1. Weed species, their relative abundance and their effect on crop yields. Can. J. Plant Sci. 40:457-467.

56. Friesen, H.A. 1961. Some factors affecting the control of wild oats with barban. Weeds 9:185-194.

57. Friesen, H.A. 1973. Herbicides popular in Western Canada. Weeds Today 4(3):20-22.

58. Friesen, H.A. and K.E. Bowren. 1973. Factors affecting the control of wild oats in rapeseed with trifluralin. Can. J. Plant Sci. 53:199-205.

59. Friesen, H.A., P.A. O'Sullivan, and W.H. Vanden Born. 1976. HOE 23408, a new selective herbicide for wild oats and green foxtail in wheat and barley. Can. J. Plant Sci. 56:567-578.

60. Gealy, D.R. and F.W. Slife. 1982. Effect of selective postemergence grass herbicides on intact leaf photosynthesis and growth of corn and soybean. Abstr. Weed Sci. Soc. Amer. p. 88.

61. Guide to weed control in Alberta : Part 1-Chemical. 1981. Agdex 641-9, Alberta Agric., Edmonton, Alta. 132 pp.

62. Hakansson, S. and B. Wallgren. 1971. Experiments with *Agropyron repens* (L.) Beauv. X. Individual and combined effects of division and burial of the rhizome and competition from a crop. Swedish J. Agric. Res. 1:239-246.

63. Hakansson, S. and B. Wallgren. 1976. *Agropyron repens* (L.) Beauv., *Holcus mollis* L. and *Agrostis gigantea* Roth. as weeds - some properties. Swedish J. Agric. Res. 6:109-120.

64. Harger, T.R., R.W. Prince, and P.R. Nester. 1982. Comparison of BAS 9052, PP 009, and RO 13-8895 for postemergence control of grasses in soybeans. Abstr. Weed Sci. Soc. Amer. p. 10.

65. Hatzios, K.K. 1982. Studies on the mode of action of the herbicide BAS 9052 OH. Abstr. Weed Sci. Soc. Amer. p. 5.

66. Hayes, R.M. and C.S. Williams. 1981. Evaluation of herbicides for postemergence johnsongrass control in soybeans. Proc. South. Weed Sci. Soc. 34:49.

67. Helms, R.L., W.J. Blackman, and B.D. Reynolds. 1980. Comparisons of BAS 9052, KK 80, and MBR 18337 for the control of grasses in cotton. Proc. South. Weed Sci. Soc. 33:55.

68. Hoagland, D.R. and D.I. Arnon. 1950. The water culture method for growing plants without soil. Calif. Agric. Expt. Sta. Circ. 347:32.

69. Hoagland, R.E. and S.O. Duke. 1981. Glyphosate : A unique herbicide. Weeds Today 12(2):21-23.

70. Holm, L.G., D.L. Plucknett, J.V. Pancho, and J.P. Herberger. 1977. The World's Worst Weeds, Distribution and Biology. East-West Centre Books, University Press of Hawaii, Honolulu, Hawaii. 309 pp.

71. Howell, S. and R. Frans. 1980. Preliminary studies on control of bermudagrass in cotton. Proc. South. Weed Sci. Soc. p. 29.

72. Hsiao, T.C. 1973. Plant responses to water stress. Ann. Rev. Plant Physiol. 24:519-570.

73. Ingram, G.H. and A.E. Slater. 1980. NP55 - a new herbicide for grass weed control in vegetable, fruit, fodder, and processing crops. Proc. British Crop Prot. Conf. - Weeds 15:39-46.

74. Ivany, J.A. 1982. Control of quackgrass with BAS 9052. Abstr. Weed Sci. Soc. Amer. pp. 30-31.

75. Jeffcoat, B. and W.N. Harris. 1973. Selectivity and mode of action of ethyl (±)-2-(*N*-benzoyl -3,4-dichloroanilino) propionate in the control of *Avena fatua* in cereals. Pestic. Sci. 4:891-899.

76. Jeffcoat, B., W.N. Harries, and D.B. Thomas. 1977. Factors favouring the choice of flamprop-methyl, methyl(±)-2-(*N*-(3-chloro-4-fluorophenyl) benzamido) propionate, for the control of *Avena* species in wheat. Pestic. Sci. 8:1-12.

77. Jensen, W.A. 1962. Histological procedures. *In*: Botanical Histochemistry. W.H. Freeman and Company, New York. pp. 55-99.

78. Johnsey, P.S. and T.R. Harger. 1982. Visible and microscopic effects of BAS 9052 on johnsongrass (*Sorghum halepense* (L.) Pers.) and itchgrass (*Rottboellia exaltata* L.F.) Abstr. Weed Sci. Soc. Amer. p. 85.

79. Kaufman, P.B. and S.J. Cassell. 1963. Striking features in the development of internodal epidermis in the oat plant (*Avena sativa*). The Michigan Botanist 2:115-121.

80. Kaufman, P.B., S.J. Cassell, and P.A. Adams. 1965. On the nature of intercalary growth and cellular differentiation in internodes of *Avena sativa*. Bot. Gaz. 126:1-13.

81. Kimura, F., R. Nishiyama, K. Fujikawa, I. Yokomichi, T. Haga, and N. Sakashita. 1981. Fluazifop-butyl, a new type of herbicide with selectivity between gramineous weeds and broadleaf crops. Proc. Asian-Pacif. Weed Sci. Soc. Conf. 8:433-437.

82. Korsmo, E. 1954. Wild oats (*Avena fatua* L.). *In*: Anatomy of Weeds. Kristes Boktrykkeri, Oslo, Norway. pp. 30-31.

83. Kriz, C. and M.M. Schreiber. 1982. Intensity of interspecific interference on growth of foxtails (*Setaria* spp.) and soybeans. Abstr. Weed Sci. Soc. Amer. p. 62.

84. Kurtz, M.E. 1981. Barnyardgrass control in soybeans following rice. Proc. South. Weed Sci. Soc. 34:52.

85. Leakey, R.R.B. and R.J. Chancellor. 1978. Regeneration from rhizome fragments of *Agropyron repens* (L.) Beauv. III. Effects of nitrogen and temperature on the development of dominance amongst shoots on multinode fragments. Ann. Bot. 42:197-204.

86. Martin, J.H., W.H. Leonard, and D.L. Stamp. 1976. Principles of Field Crop Production. MacMillan Publishing Co., New York. pp. 691-812.

87. McAvoy, W.J. 1982. Todays herbicide : POAST. Weeds Today 13(2):7-8.

88. McIntyre, G.I. 1970. Studies on bud development in the rhizome of *Agropyron repens* 1. The influence of temperature, light intensity, and bud position on the pattern of development. Can. J. Bot. 48:1903-1909.

89. Metcalf, C.R. 1960. Anatomy of the Monocotyledons. Oxford Univ. Press, Ames House, London. Vol I. p. 736.

90. Minjas, A.N., V.C. Runeckles, and B.G. Todd. 1982. Analysis of the competitive interactions between rapeseed (*Brassica napus* L.) and two annual weeds - redroot pigweed (*Amaranthus retroflexus* L.) and green foxtail (*Setaria viridis* (L.) Beauv.). Abstr. Weed Sci. Soc. Amer. p. 63.

91. Minjas, A.N., V.C. Runeckles, and B.G. Todd. 1982. Competitive interactions between barnyardgrass (*Echinochloa crus-galli* (L.) Beauv.). and green foxtail (*Setaria viridis* (L.) Beauv.). Abstr. Weed Sci. Soc. Amer. .p. 130.

92. Morrison, I.N., B.D. Hill, and L.G. Dushnicky. 1979. Histological studies on the effects of benzoylprop ethyl and flamprop methyl on growth and development of wild oats. Weed Res. 19:385-393.

93. Morrison, I.N., M.G. Owino, and E.H. Stobbe. 1981. Effects of diclofop on growth, mitotic index, and structure of wheat (*Triticum aestivum*) and wild oats (*Avena fatua*) adventitious roots. Weed Sci. 29:426-432.

94. Muzik, T.J. 1976. Influence of environmental factors on toxicity to plants. *In:* L.J. Audus, ed. Herbicide: Physiology, Biochemistry, Ecology. Academic Press, London, Vol. 1. pp. 203-247.

95. Nalewaja, J.D. 1970. Wild oat : a persistent and competitive weed. Weeds Today 1(2):10-13.

96. Neidermyer, R.W. and J.D. Nalewaja. 1974. Barban selectivity for wild oat in wheat. Weed Sci. 22:476-480.

97. Nilson, E.B., V.A. Johnson, and C.O. Gardner. 1957. Parenchyma and epidermal cell length in relation to plant height and culm internode length in winter wheat. Bot. Gaz. 119:38-43.

98. Oliver, L.R., D.G. Mosier, and O.W. Howe. 1982. A comparison of new postemergence herbicides for control of annual grasses. Abstr. Weed Sci. Soc. Amer. p. 17.

99. Oliver, L.R. and M.M. Schreiber. 1971. Differential selectivity of herbicides on six *Setaria* taxa. Weed Sci. 19:428-431.

100. O'Sullivan, P.A., R.J. Schraa, and W.H. Vanden born. 1975. Wild oat control in wheat. Expert Committee on Weeds, Res. Rep., West. Sect., Part 2. pp. 492-493.

101. Pallett, K.E. 1980. The mechanisms of activity and selectivity of the wild oat herbicides. Proc. British Crop Prot. Conf. - Weeds 15:843-854.

102. Palmer, J.H. and G.R. Sagar. 1963. *Agropyron repens* (L.) Beauv. Biological flora of the British Isles. J. Ecol. 51:783-794.

103. Pavlychenko, T.K. and J.B. Harrington. 1934. Competitive efficiency of weed and cereal crops. Can. J. Res. 10:77-91.

104. Pearson, J.O. 1980. Post-emergence graminicide for broadleaf crops. Abstr. Weed Sci. Soc. Amer. p. 114.

105. Phipps, P. and J.F. Roebuck. 1980. Agricultural Development and Advisory Service/Weed Research Organisation *Avena fatua* case studies. Proc. British Crop Prot. Conf. - Weeds 15:407-414.

106. Plowman, R.E., W.C. Stonebridge, and J.N. Howtree. 1980. Fluazifop-butyl - a new selective herbicide for the control of annual and perennial grass weeds. Proc. British Crop Prot. Conf. - Weeds 15:29-30.

107. Quail, P.H. and O.G. Carter. 1968. Survival and seasonal germination of seeds of *Avena fatua* and *Avena ludoviciana*. Austr. J. Agric. Res. 19:721-729.

108. Rahman, R. and R. Ashford. 1972. Control of green foxtail with trifluralin. Weed Sci. 20:23-27.

109. Ready, E.L. 1982. Fusilade herbicide - a new selective postemergence herbicide for grass weeds. Weeds Today 13(2):20 p.

110. Ready, E.L., III. and J. Wilkerson. 1982. Postemergence control of rhizome johnsongrass (*Sorghum halepense* (L.) Pers.) with PP 009 as affected by drought stress. Abstr. Weed Sci. Soc. Amer. p. 15.

111. Rogan, P.G. and D.L. Smith. 1974. Patterns of translocation of ^{14}C-labelled assimilates during vegetative growth of *Agropyron repens* (L.) Beauv. Z. Pflanzenphysiol. 73:405-414.

112. Ross, W.M. 1955. Associations of morphological characters and earliness in oats. Agron. J. 47:453-457.

113. Rosser, S.W. and W.W. Witt. 1981. Activity of BAS 9052, CGA 82725 and RO 13-8895 on johnsongrass (*Sorghum halepense*) and giant foxtail (*Setaria faberii*). Proc. South. Weed Sci. Soc. 34:99.

114. Sarpe, N. and C. Dinu. 1980. The control of *Sorghum halepense* growing from seeds and rhizomes using fluazifop butyl, alloxidim sodium, alachlor, diphenamid and trifluralin in soybean. Proc. British Crop Prot. Conf. - Weeds 15:565-572.

115. Sawhney, R. and J.M. Naylor. 1980. Dormancy studies in seed of *Avena fatua*. 12. Influence of temperature on germination behaviour of nondormant families. Can. J. Bot. 58:578-581.

116. Selleck, G.W. 1961. Recent advances in the chemical control of wild oats. Weeds 9:60-71.

117. Seth, A.K. and D.W.R. Headford. 1981. Annual and perennial grass weed control in Asia-pacific region with fluazifop-butyl. Proc. Asian-Pacif. Weed Sci. Soc. Conf. 8:443-447.

118. Sharma, M.P., D.K. McBeath, and W.H. Vanden Born. 1976. Studies on the biology of wild oats. 1.Dormancy, germination and emergence. Can. J. Plant Sci. 56:611-618.

119. Sharma, M.P. and W.H. Vanden Born. 1978. The biology of Canadian Weeds. 27. *Avena fatua* L. Can. J. Plant Sci. 58:141-157.

120. Sharma, M.P. and W.H. Vanden Born. 1983. Crop competition aids efficacy of wild oat herbicides. Can. J. Plant Sci. (In press).

121. Smith, L.L., Jr., H. Johnston, B.C. Gerwick, and E.A. Egli. 1982. DOWCO 453 - a new postemergence herbicide for selective annual and perennial grass control in broadleaved crops. Abstr. Weed Sci. Soc. Amer. p. 107.

122. Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics; A Biometrical Approach. Second Edition, McGraw-Hill, New York. pp. 253-256.

123. Stonebridge, W.C. 1981. Selective postemergence grass weed control in broad-leaf arable crops. Outlook on Agric. 10:385-392.

124. Swisher, B. and F.T. Corbin. 1982. The behaviour of sethoxydim in soybean and johnsongrass (*Sorghum halepense* (L.) Pers.). Part I. Penetration, distribution, and metabolism in intact plants. Abstr. Weed Sci. Soc. Amer. p. 126.

125. Swisher, B. and F.T. Corbin. 1982. The behaviour of sethoxydim in soybean and johnsongrass (*Sorghum halepense* (L.) Pers.). Part II. Uptake and metabolism in cell cultures. Abstr. Weed Sci. Soc. Amer. p. 93.

126. Tingey, D.C. 1961. Longevity of seeds of wild oats, winter rye, and wheat in cultivated soil. Weeds 9:607-611.

127. Vanden Born, W.H. 1971. Green foxtail : seed dormancy, germination and growth. Can. J. Plant Sci. 51:53-59.

128. Velovitch, J.J. 1982. New postemergence herbicides for controlling grass weeds in soybeans. Weeds Today 13(2):12-18.

129. Werner, P.A. and R. Rioux. 1977. The biology of Canadian weeds. 24. *Agropyron repens* (L.) Beauv. Can. J. Plant Sci. 57:905-919.

130. Williams, E.D. 1970. Studies on the growth of seedlings of *Agropyron repens* (L.) Beauv. and *Agrostis gigantea* Roth. Weed Res. 10:321-330.

131. Williams, E.D. and P.J. Attwood. 1971. Seed production of *Agropyron repens* (L.) Beauv. in arable crops in England and Wales in 1969. Weed Res. 11:22-30.

132. Wilson, B.J. 1978. The long term decline of a population of *Avena fatua* L. with different cultivations associated with spring barley cropping. Weed Res. 18:25-31.

133. Wilson, B.J. and G.W. Cussans. 1975. A study of the population dynamics of *Avena fatua* L. as influenced by straw burning, seed shedding and cultivations. Weed Res. 15:249-258.

134. Wilson, H.P. and T.E. Hines. 1980. Post-emergence control of annual grasses in soybeans. Proc. Northeast. Weed Sci. Soc. 34:6-10.

135. Wittmann, J. and A. Borgo. 1981. Cietoxidim or (BAS 9052H), a new herbicide to control grasses post-emergence in soybeans and cotton. Weed Abstr. 30(9):347.

136. Wood, H.E. 1953. The occurrence and the problem of wild oats in the Great Plains region of North America. Weeds 2:292-294.

APPENDIX

Table I. Wild oat and volunteer barley control in rapeseed (1980).

Treatment†	Rate kg/ha	Wild oats Score Aug 6	Wild oats Culms /m²‡	Wild oats D.W. g/m²‡	Vol. barley Score Aug 6	Vol. barley Culms /m²‡	Vol. barley D.W. g/m²‡
Weedy check		0	547 a	434 a	0	417 a	790 a
BAS 9052 2 LS	0.15	7	130 b	74 b	5	216 b	301 b
BAS 9052 3 LS	0.15	8	19 c	5 c	5	191 b	257 b
BAS 9052 5 LS	0.15	8	49 c	28 c	9	2 c	1 c
BAS 9052 2 LS	0.25	9	8 c	2 c	7	38 c	23 c
BAS 9052 3 LS	0.25	9	14 c	3 c	7	70 c	93 c
BAS 9052 5 LS	0.25	9	15 c	3 c	9	1 c	1 c
BAS 9052 2 LS	0.40	9	13 c	2 c	8	32 c	24 c
BAS 9052 3 LS	0.40	9	10 c	7 c	9	5 c	2 c
BAS 9052 5 LS	0.40	9	6 c	2 c	9	0 c	0 c

†LS refers to leaf stage of wild oats at the time of treatment. Volunteer barley plants were at 3-, 4-, and 6-leaf stage at the time of treatment.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Table II. Green foxtail control in rapeseed (1980).

Treatment†	Rate kg/ha	Green foxtail Score Aug 6	Green foxtail Dry wt. g/m²‡	Rape Score Aug 6	Rape Yield g/m²‡
Weedy check		0	50 b	9	201 ab
BAS 9052 2 LS	0.03	6	76 ab	9	149 bc
BAS 9052 4 LS	0.03	4	128 a	7	36 d
BAS 9052 2 LS	0.08	8	23 b	9	148 bc
BAS 9052 4 LS	0.08	7	64 ab	6	76 d
BAS 9052 2 LS	0.15	9	8 b	9	226 a
BAS 9052 4 LS	0.15	7	62 ab	2	31 d
TF 1169 2 LS	0.35	8	13 b	9	148 bc
TF 1169 4 LS	0.35	7	67 ab	6	87 cd

†LS refers to leaf stage of green foxtail at the time of treatment.
‡Numbers in the same column followed by the same letter are not significantly different according to Duncan's New Multiple Range Test at $P \leq 0.05$.

Table III. LSD values at P=.05 on the length of the fourth and third internodes of wild oats.

Herbicide	Internode‡	LSD values† Days after treatment 2	5	9	14
BAS 9052 OH	In 4	0.12	NS	0.43	0.39
	In 3	0.33	NS	0.64	0.63
TF 1169	In 4	NS	0.22	0.15	0.61
	In 3	NS	0.58	0.99	1.51
DOWCO 453	In 4	NS	0.71	1.05	0.57
	In 3	NS	NS	NS	NS

†The data for each internode were analyzed separately for each harvesting time.
NS refers to non-significant difference.
‡The elongation of the second internode was not significantly different from the control during 14 days after treatment.

Table IV. Weather data (1980).

Date	Temperature Min.	Temperature Max.	R.H.(%)	Rainfall (mm)	Treatment†
May 23	11.0	11.5	96	8.9	
May 24	7.0	9.0	97	0.6	
May 25	7.0	8.5	97	8.3	
May 26	6.5	10.5	100	12.2	
May 27	6.0	8.5	97	1.8	
May 28	4.5	13.5	84	2.0	
May 29	6.0	13.5	62	0.6	
May 30	**1.5**	**12.0**	**86**	**0.7**	**W.O. 2 LS**
May 31	-2.5	20.5	60	- -	
June 1	8.0	20.5	58	18.0	
June 2	12.0	19.5	87	3.0	
June 3	11.0	14.0	75	14.0	
June 4	7.5	15.5	89	2.8	
June 5	7.0	13.5	58	1.4	
June 6	1.0	12.5	70	0.5	
June 7	**1.5**	**17.0**	**44**	**- -**	**W.O. 3 LS**
June 8	6.5	23.5	55	- -	
June 9	8.0	26.5	51	- -	
June 10	13.0	26.0	56	4.0	
June 11	14.5	23.5	66	- -	
June 12	7.0	24.0	70	- -	
June 13	**9.0**	**25.0**	**56**	**- -**	**W.O. 5 LS**
June 14	11.0	23.0	75	- -	
June 15	11.0	25.0	56	- -	

†W.O. refers to wild oats and LS refers to leaf stage of the weed at the time of treatment.

Table V. Weather data (1981).

Date	Temperature Min.	Temperature Max.	R.H.(%)	Rainfall† (mm)	Treatment‡
May 23	10.4	23.5	77	0.2	
May 24	10.0	18.3	30	2.2	
May 25	7.6	24.3	35	- -	
May 26	12.5	25.3	59	- -	
May 27	2.2	16.8	66	3.2	
May 28	7.6	21.5	82	1.4	
May 29	3.8	18.1	58	0.8	
May 30	8.0	22.0	61	- -	
May 31	10.9	24.0	88	2.4	
June 1	9.0	15.0	61	10.2	
June 2	**10.5**	**21.1**	**68**	**T**	**W.O. 2 LS**
June 3	10.0	24.4	94	10.6	
June 4	6.6	19.1	59	2.0	
June 5	4.0	19.3	35	- -	
June 6	4.4	20.3	73	T	
June 7	2.0	18.5	39	0.6	
June 8	4.1	18.6	51	- -	
June 9	4.2	19.6	41	- -	
June 10	5.0	18.4	55	- -	
June 11	**3.3**	**17.6**	**68**	**3.0**	**W.O. 5 LS**
June 12	2.0	15.7	73	2.2	
June 13	8.1	18.9	73	T	
June 14	3.1	19.1	69	0.2	
June 15	5.1	21.8	57	0.2	

†T refers to trace amounts of rainfall.
‡W.O. refers to wild oats and LS refers to leaf stage of the weed at the time of treatment.